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ABSTRACT

To evolve a new methodology and system for teaching physics to students aspiring to become (or to become more competent as) technicians in a variety of technologies, this research and development effort was initiated. The project's thesis stemmed from a notion that the study of physics would be more accepted and assimilated by students if concepts were systematically unified and presented in practical examples directly related to the technology under study. Appropriate subject matter was unified under twelve concepts; instructional materials were prepared to introduce and apply the concepts. Applications were limited in scope to a single energy system (electrical, mechanical, fluidal, and thermal). Following this plan of concepts and applications, 130 pamphlets (modules) of instructional materials were prepared. Appropriate portions of these materials were used in three different technology programs in three different postsecondary technical schools. Initial indications suggest that the thesis and materials are valid. A follow-on project is to provide additional materials and further use-analyses in technical schools and in industrial training programs. (Appendixes include [1] example concept module: 3-0, "Work and Energy," [2] example application module: 6T2 "Heat Flow through Insulation," [3] module control forms, [4] modules used in experimental instructional programs, and [5] a pamphlet: "Unified Technical Concepts.") (Author/CSS)

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ED169222

FINAL REPORT

PROJECT NO. 498AH60153
GRANT NO. G007603926

UNIFIED TECHNICAL CONCEPTS - PHASE I

(Modularizing Instructional Materials Using Applications of Technical Concepts)

TECHNICAL EDUCATION RESEARCH CENTER - SOUTHWEST
4201 Lake Shore Drive, Suite 111
Waco, Texas 76710

September 30, 1978

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ABSTRACT

The purpose of this U. S. Office of Education sponsored (Grant No. G007603926) research and development effort (Project No. 498AH60153) was to evolve a new methodology and system for teaching physics to students aspiring to become (or to become more competent as) "technicians" in any of a variety of technologies. The thesis for this project stemmed from a notion that physics, as a subject of study, would be more palatable to amd more easily assimilated by such students if its concepts were 1) systematically unified and 2) presented in practical examples directly related to the technology under study. After intensive effort, appropriate subject matter was unified under 12 concepts. Instructional material was prepared to introduce these 12 concepts and to present specific applications under each. Applications were limited in scope to a single energy system (electrical, mechanical, fluidal and thermal). Following this plan of concepts and applications, 130 pamphlets (modules) of instructional materials were prepared. Appropriate portions of these materials were used in three different technology programs in three different post-secondary technical schools. Initial indications suggest that the thesis and the materials are valid. A follow-on project is to provide additional materials and further use-analyses, both in technical schools and in industrial training programs.

ACKNOWLEDGMENTS

This project was conceived out of needs expressed by many faculty members and administrators of two-year, postsecondary institutions, and out of the industrial experience of the Project Director: however, ideas for a unified approach to physics presented as early as the turn of the century, were specified in 1972 in a curriculum development project for Electromechanical Technology, directed by Dr. Maurice W. Roney.

Encouragement to undertake the task of "restructuring physics" was provided by Dr. Walter J. Brooking, Technical Consultant, U. S. Office of Education. The project tasks have been conducted by the TERC-SW staff (Vernon Woolf, Carl Lansford and Bruce Lube), assisted by Chief Technical Consultant and Editor, Dr. Leno S. Pedrotti, U. S. Air Force Institute of Technology. Pilot testing of instructional materials has been conducted at three innovative schools: Texas State Technical Institute, Harlingen, Texas; North Central Technical Institute, Wausau, Wisconsin; Camden County College, Blackwood, New Jersey.

Sponsorship of this project was provided by a grant from the Research Division, U. S. Office of Education, Bureau of Adult and Occupational Education, Mr. Glen Boerrigter, Branch Chief and Ms. Velma Brawner, Project Officer.

Daniel M. Hull
Project Director

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SECTION I
INTRODUCTION

The increasing complexity of modern industry and the scope of emerging energy-related technologies is rapidly changing occupational skill requirements. A new generation of "systems" technicians with broad, interdisciplinary training is needed. Employers, while searching for such technicians, are retraining their existing employees to perform these technically diverse tasks.

Meanwhile, emerging and changing technologies, which require such technicians, also call for upgrading in the form of cross-training in different technical areas of physics to respond rapidly to new technological opportunities.

Both of these situations demand a more flexible method of physics instruction.

A. BACKGROUND

Physics is the foundation for learning many technical occupations. Even so, physics is one of the most confusing, least understood and seemingly irrelevant courses (as perceived by beginning students) in a technology curriculum. Technical physics for occupational curricula has two basic problems.

1. At most two-year, postsecondary technical institutions, physics is taught in a traditional manner (e.g., as mechanics, heat, electricity, magnetism, sound, light and possibly atomic physics). In studying these isolated fields, events are described for which there are analogous phenomena in the other fields. These phenomena (or concepts) are introduced over and over in each field with no attempt to unify them by describing their analogous nature.

Not only is this process inefficient in terms of time spent, but it provides the modern technician with no preparation for technically diversified work (i.e., development, operation or maintenance of equip-

ment that contains combinations of two or more electrical, mechanical, thermal, fluid or optical subsystems).

2. Just as little attempt is made to effectively relate the phenomena studied in physics to one another, rarely is an effort made to relate physics to "real world" equipment and instrumentation. Students rarely are exposed to or impressed with an understanding of how the principles studied in physics courses apply to their technical specialties. Physics laboratories almost always use special apparatus for experiments, rather than using actual equipment and devices encountered in the real world of work.

Another reason for the seeming irrelevance of technical physics is that the subject is treated broadly rather than being tailored to a specific technology. A student enters an occupational program to study a specialized field, and courses unrelated to that field do little to promote the interest and enthusiasm that are vital to effective learning.

B. NEED

As noted, ideas for unification of physics date back to the turn of the century; however, details regarding the specific design of such a plan were presented only a few years ago by Austin E. Fribance and Maurice W. Roney[1] in a project to develop a curriculum and supporting instructional materials for Electromechanical Technology (EMT), 1968-73. Soon thereafter a theoretical text was prepared by James E. Court and Edward J. Dierauf[2] (out of necessity) to teach physics for students of Electromechanical Technology at City College of San Francisco. While reviewing this text (and in subsequent discussions with these authors), the TERC-SW staff discovered a lack of practical, hands-on laboratory activities to complement it.

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[1] Project #8-0219, U. S. Office of Education Grant #0EG-7-8000219-0057-(085).

[2] Court, James E. and Dierauf, Edward J. Unified Concepts in Physics and Engineering. San Francisco, CA: City College of San Francisco, 1975.

C. PLAN

The original idea for this Office of Education grant-sponsored project was to perform the required research and to develop a series of laboratory-oriented instructional modules to complement the Court and Dierauf text. Wherever possible, the Electromechanical Technology materials mentioned earlier were to be used as a resource for the new modules. The intention, however, was to develop a system (and supporting materials) for teaching technical physics to first-year students in various technical curricula at typical postsecondary technical institutes and junior/community colleges throughout the country.

The Office of Education awarded a grant to TERC-SW in July, 1976, to accomplish the following tasks:

- Assemble an advisory team of technical specialists and educators to guide and assist in the research, development and evaluation of the project.
- Perform research to identify 1) the format of the delivery system, 2) the content and structure of the instructional modules, 3) the level of student for which the system was to be designed and 4) the technical specialty curricula that the physics would support.
- Develop approximately 150 laboratory-oriented, application instructional modules to support the following 16 unified concepts:

  Force.
  Rate.
  Resistance and Energy Loss.
  Potential Energy.
  Kinetic Energy.
  Resistance/Capacitance System.
  Resistance/Inertance System.
  Oscillation.
  Sinusoidal System.
  Resonance.
  Transformation.
  Load Matching.

Amplification.
Transduction.
Control (Feedback Stability).
Radiated (Wave) Energy.

A generalized matrix shows the compatibility of the proposed modules to each unified concept (Figure 1). It was envisioned that each module would be approximately 10 pages long.

- Prepare an Instructor's Guide.
- Conduct limited dissemination activities with schools.

UNIFIED PHYSICS CONCEPT	MECHANICS APPLICATIONS MODULES	ELECTRICAL APPLICATIONS MODULES	FLUIDS APPLICATIONS MODULES	THERMAL APPLICATIONS MODULES
1 Force	1M1 1M2 1M3 ⋮	1E1 1E2 1E3 ⋮	1F1 1F2 1F3 ⋮	1T1 1T2 1T3 ⋮
2 Rates	2M1 2M2 2M3 ⋮	2E1 2E2 2E3 ⋮	2F1 2F2 2F3 ⋮	2T1 2T2 2T3 ⋮
3 Resistance and Energy Loss	3M1 Friction on a Horizontal Plane 3M2 Friction on an Inclined Plane 3M3 Friction in Bearings 3M4 Lubrication 3M5 Shock Absorbers	3E1 Ohm's Law * 3E2 Resistance in a Wire 3E3 Resistance in Series and Parallel 3E4 Non-Linear Resistance 3E5 Power and Energy Loss in a Resistor	3F1 Resistance to * Liquid Flow in Large Pipes 3F2 Resistance to Liquid Flow in Capillary Tubes 3F3 Air Flow in Ducts 3F4 Viscosity of Liquids	3T1 Thermal Conductivity 3T2 Thermal Insulation
4 Potential Energy	4M1 4M2 4M3 ⋮	4E1 4E2 4E3 ⋮	4F1 4F2 4F3 ⋮	4T1 4T2 4T3 ⋮
16 Waves and Radiated Energy	16M1 16M2 16M3 ⋮	16E1 16E2 16E3 ⋮	16F1 16F2 16F3 ⋮	16T1 16T2 16T3 ⋮

Figure 1. Relationship of proposed application modules to each unified physics concept (example matrix).

D. SUMMARY OF RESULTS

Research, very early in the project, led to a realignment of objectives and a different format for the instructional system. For reasons explained in Section III of this report, the Project Director, in collaboration with the Office of Education Technical Consultant, concluded that the Court and Dierauf text was an unsuitable base for presenting the unified concepts to average technical students. Rather, a system of twelve concept modules and one concept-level module were to be developed according to the listing below:

"Matter, Units and Measurements" - Concept-level module.

"Force and Forcelike Quantities" -
"Work and Energy" -
"Rate" -
"Momentum" -
"Resistance" -
"Power" -
"Potential and Kinetic Energy" -
"Force Transformation" -
"Energy Transformation" -
"Vibration and Waves" -
"Time Constant" -
"Radiation" -

} Concept Modules.

These modules average between 30 and 35 pages in length and, typically, each contains four hardware demonstrations to illustrate the concept in each of the four energy forms (when applicable).

By the conclusion of this project (Phase I), on June 30, 1978, the following, revised project tasks were accomplished:

- The UTC Advisory Team (Appendix A) was an active and working group, consisting of technical experts, school administrators and faculty at the three schools using the materials experimentally.

- Extensive research (more than anticipated) had been performed to reorganize physics into the present UTC format (presented in Section II) and to identify relevant topics and content for concept and application modules.
- Twelve concept modules, one concept-level module (30-35 page average) and 117 application modules were developed.
- The materials used at the three schools have been revised in accordance with user suggestions.
- The UTC Instructor's Guide has been developed, reviewed by 9 educators and 2 industrial representatives and revised accordingly.
- Dissemination activities have been conducted, yielding 84 organizations interested in implementing a UTC program (Appendix B). Two additional schools (other than the original test sites) already have begun to use UTC modules in their physics departments.

A subsequent grant (Phase II) has been awarded to TERC-SW to continue this work; that is, to develop additional modules, to continue dissemination, to encourage continued school use and to pilot test the program in industry to retrain technicians.

SECTION II

UTC (UNIFIED TECHNICAL CONCEPTS) SYSTEM

UTC, even by its name, implies a new approach to teaching physics. Applied physics phenomena become focal points called "concepts" (12 in all). In a "concept module," each phenomenon is examined in terms of its applicability to one or more of the four energy systems (mechanical, fluidal, electrical, thermal).

A module that relates a concept to a specific example or piece of equipment in an energy system is called an "application module." The latter (117 modules in Phase I) make up the bulk of the learning materials developed.

Heavy emphasis is placed on analogies - or relationships - between basic concepts applied to traditional fields of physics and engineering, such as resistance, which occurs in many forms (electrical resistance, mechanical resistance and so on). Mathematical expressions for these various kinds of resistance may differ, but basic similarities can be noted. As a result, resistance becomes, and is presented as, a unified concept in a concept module. Meanwhile, examples of electrical, fluidal mechanical and thermal resistance are separate applications, presented in application modules that include student-oriented laboratory procedures that employ practical and appropriate (real world) equipment.

By prudent selection, curricula may be designed to satisfy the needs of students with similar or dissimilar interests and backgrounds. All UTC modules assume the student has completed a secondary school (high school) program or its equivalent, including one year of high school algebra. Those students not meeting these basic prerequisites may need additional counseling or academic support to strengthen their background, especially in mathematics. Other mechanisms for instructional implementation are discussed following a description of the design characteristics of UTC.

Four terms ("support module," "energy system," "concept module" and "application module") are introduced in UTC and must be defined.

A. SUPPORT MODULE

At the top of Table One, a concept-level module (1-0, "Matter, Units and Measurements") provides an introduction to the physical world of matter and should be considered prerequisite information for all concept modules. Other support modules listed in Table One are designed as specific prerequisites to be used just prior to the study of specific concept or application modules (as indicated); for example: support module, "Logarithms and Powers of 10," should be introduced just prior to a module that uses logarithms, if the instructor perceives a need for student enrichment.

B. ENERGY SYSTEM

The term "energy system" is used to describe energy in various forms, similar to its use in traditional physics (e.g., mechanics, electronics, heat, fluid and so on).

C. CONCEPT MODULE

Concept modules are the "bridges" that connect these various branches. A team of physics educators, industrial engineers and technology instructors cataloged the physical phenomena common to technical training into twelve concepts (Table One). Note: Support Module 1-0, "Matter, Units and Measurements," is not a physical "concept" in the same sense as the other twelve; but conveniently fits with them as a prerequisite, concept-level module and is always included at the beginning of the list.

Each concept introduces the phenomenon identified by its title, and relates it to every system. An exemplary application provides the relationship between various energy systems and the concept. In most instances, a concept module is presented as a group discussion or lecture, with suggested demonstrations and laboratory procedures provided at the end of the module to illustrate each energy system. (An example concept module is included as Appendix C.) A summary of each concept is available in chart form and may be displayed in the classroom.

MATTER, UNITS AND MEASUREMENTS	1-0 INTRODUCTION TO CONCEPTS: PROPERTIES & MEASUREMENT OF MATTER			
	S6 Dimensional Analysis			
CONCEPTS	**ENERGY SYSTEM**			
	ELECTRICAL	**MECHANICAL**	**FLUIDAL**	**THERMAL**
FORCE AND FORCELIKE QUANTITIES	2-0 CONCEPT MODULE: QUANTITIES THAT CAUSE MOVEMENT			
	2E1 Potential Difference 2E2 Series and Parallel Arrangements of Sources of Electromotive Forces 2E3 Magnetic Force 2E4 Electric Force 2E5 Volt-Ohm-Milliammeter 2E6 Lead-Acid Storage Battery	2M1 Resolution and Composition of Vectors 2M2 Torque and Equilibrium 2M3 Structural Forces and Torque 2M4 Stress and Strain	2F1 Atmospheric Pressure 2F2 Density, Buoyancy and Specific Gravity 2F3 Hydraulic Jack 2F4 Manometers	2T1 Thermometers 2T2 Temperature Difference and Heat Flow 2T3 Thermal Stress
WORK AND ENERGY	3-0 CONCEPT MODULE: WORK = FORCELIKE QUANTITY X DISPLACEMENT			
			3F1 Work Done by a Water Pump 3F2 Work Done by a Hydraulic Lift	3T1 Heat of Fusion 3T2 Heat of Vaporization 3T3 Fundamentals of Air Conditioning 3T4 Calorimeter Experiment
RATE	4-0 CONCEPT MODULE: RATE = DISPLACEMENT / TIME ELAPSED			
	4E1 Direct Current	4M1 Graphical Approach to Rectilinear Motion 4M2 Velocity at a Constant Acceleration 4M3 Displacement at a Constant Acceleration	4F1 Flow Rate Measurement with a Venturi Meter	4T1 Heating, Cooling Rate 4T2 Rate of Heat Conduction
MOMENTUM	5-0 CONCEPT MODULE: FORCELIKE QUANTITY X TIME APPLIED = INERTIAL QUANTITY X RATE			
	5E1 Inductance Coils	5M1 Angular Momentum/Flywheel	5F1 Rocket Engines	
RESISTANCE	6-0 CONCEPT MODULE: RESISTANCE = FORCELIKE QUANTITY X RATE			
	6E1 Ohm's Law 6E2 Internal Resistance in a Battery 6E3 Series and Parallel Resistors 6E4 Conductors, Semiconductors and Insulators 6E5 Resistance of Conductors 6E6 Thermistors	6M1 Static and Kinetic Friction 6M2 Effect of Lubricants 6M3 Rolling Friction	6F1 Laminar and Turbulent Flow 6F3 Shock Absorber 6F4 Viscosity	6T1 Thermal Conductivity 6T2 Heat Flow Through Insulation

POWER	**7-0 CONCEPT MODULE: POWER = WORK / TIME ELAPSED**			
	7E1 Electrical Heater 7E2 Electrical Power Measurement 7E3 Prony Brake 7E4 Efficiency of Electric Motors and Generators	7M1 Horsepower		7T2 Heat Exchanger
POTENTIAL AND KINETIC ENERGY	**8-0 CONCEPT MODULE: CONSERVATION OF ENERGY**			
	8E1 Energy Stored in a Capacitor 8E2 Energy Stored in a Battery	8M2 Rotational Kinetic Energy (The Flywheel) 8M3 Piledriver/Forging Hammer	8F1 Energy Stored in Large Tanks/ Torricelli's Theorem 8F2 Venturi Meter 8F3 Pitot Tube 8F4 Energy Conversion in Fluid Systems	8T1 Heat Storage Systems 8T2 Electrical Equivalent of Heat 8T3 Mechanical Equivalent of Heat 3T4 Thermal Drying
FORCE TRANSFORMERS	**9-0 CONCEPT MODULE: PRINCIPLES OF SIMPLE MACHINES**			
	9E1 Electrical Transformers	9M1 Levers 9M2 Wedge-Inclined Plane 9M3 Drive Systems 9M4 Block and Tackle 9M5 Differential Hoist 9M7 Gear Trains		
ENERGY TRANSFORMERS	**10-0 CONCEPT MODULE: DEVICES TO CONVERT ENERGY FROM SYSTEM TO SYSTEM**			
	10E3 Photovoltaic Materials	10M1 Strain Gage 10M2 Accelerometer	10F1 Pressure Elements/Bourdon Tube 10F2 Fluid Flow Measuring Devices 10F3 Turbines 10F4 Aneroid Barometer 10F5 Differential Pressure Transducer	10T1 Thermal Expansion/Automobile Water Thermostat 10T2 Thermal Expansion/Bimetallic Strips 10T3 Temperature Measuring Devices 10T4 Pyrometer 10T5 Generators/Steam
VIBRATIONS AND WAVES	**11-0 CONCEPT MODULE: MECHANICAL ENERGY TRANSFER THROUGH PERIODIC MOTION**			
	11E1 Basic Characteristics of Alternating Voltage and Currents 11E2 Phase Relationships 11E3 Oscilloscope 11E4 Rectifiers	11M1 Speed of Sound in Various Materials 11M2 Reflection and Absorption of Sound Energy 11M3 Vibration Isolation	11F1 Cavity Vibration/Standing Waves 11F2 Sound Speakers 11F3 Speaker Enclosures 11F4 Reverberation Time 11F5 Resonance	
TIME CONSTANTS	**12-0 CONCEPT MODULE: QUANTITIES VARYING EXPONENTIALLY WITH TIME**			
	12E1 RC Circuits 12E2 RLC Circuits	12M1 Shock Isolation Systems/ Absorber		12T1 Response Time on Thermocouples
RADIATION	**13-0 CONCEPT MODULE: ELECTROMAGNETIC AND PARTICAL RADIATION**			
	13L1 Inverse Square Law - Spreading Light 13L2 The Optical Spectrum 13L3 Light Sources 13L4 Lasers 13L5 Stroboscope - Pulses of Light 13L6 Optical Filters - Absorption of Light 13L7 Specular and Diffuse Reflection of Light 13L8 Image Formation with Mirrors		13L9 Prisms - Refraction and Dispersion of Light 13L10 Lenses - Focusing and Spreading of Light 13L11 Interference - Testing Flat Surfaces 13L12 Diffraction Grating - Measuring the Wavelength of Light 13L13 Polarization - Reducing Glare 13L14 Holography - Three Dimensional Photography 13L15 Spectroscopy - Analysis of Light	

Table One. Matrix of modules completed in Phase I.

D. APPLICATION MODULE

While a specific number of concept modules (12) has been designed, the number of application modules remains dynamic. Each application module addresses a specific piece of equipment or single principle that relates to both a defined concept and an energy system. Table One indicates how application modules fit within each concept.

Each application module also includes practical, student-oriented, "hands-on" experiments. These experiments emphasize situations and specific equipment that will be encountered on the job.

Each application module is coded to indicate the concept and energy system being addressed: Module 6T2, "Heat Flow Through Insulation" (Appendix D) may be decoded as follows: the first number (6) indicates that it is an application module referencing concept module 6-0, "Resistance;" the "T" signifies a thermal application; and the "2" means it is second in the series of thermal application modules available under concept 6-0.

The module identification system applies to all application modules:

E = Electrical.
M = Mechanical.
F = Fluidal.
T = Thermal.
O = Optical.
N = Nuclear.

If a concept had no practical application(s) in any particular energy system no attempt was made to "force" an example into it. The application modules selected for any specific course can be determined by the instructor. An average of five (or less) per concept is suggested.

The organization of application modules into four energy systems was altered in concept 13-0, "Radiation." In this concept, radiation was divided into 1) electromagnetic radiation and 2) particle radiation. Additional applications were identified in electrical, optical and nuclear categories, and appropriate modules were prepared for these applications.

E. IMPLEMENTATION

Successful implementation of UTC was determined to be dependent upon mastery of the basic idea that mechanics, electronics, fluids and so on,

all have common characteristics. Concept modules carry that thread of commonality through the various energy systems, and every opportunity to stress this relationship is used.

A typical module contains the following sections:

- INTRODUCTION, which provides an overview of module content and an introduction to the concept or, for application modules, relationship to the concept.
- PREREQUISITES, which suggest the appropriate student background for successfully completing the module.
- OBJECTIVES, which indicate important points covered, and state what student should do to demonstrate content mastery.
- DISCUSSION, which details the module's content, and includes pertinent illustrations and relevant examples.
- LABORATORY, which demonstrates the principle(s) being presented by using technology- and industry-related equipment; includes materials list and procedures.
- SELF CHECK, which allows students to practice their content mastery with no penalties, prior to classroom examinations. Students are encouraged to review appropriate segment(s) of Discussion if unable to complete a self-check item.
- REFERENCES, which are to be used by students if more information about module topic is desired.

SECTION III
PROJECT ACTIVITIES

This research and development project consisted of a variety of activities, most of which are clearly definable and worthy of expanded discussion.

A. RESEARCH

The research conducted very early in the project led to a realignment of objectives and a different format for the instructional system. Careful examination and scrutiny of the Court and Dierauf text by the TERC-SW staff and the Advisory Committee revealed two potential problems that could have limited the effectiveness and wide-scale usefulness of the materials:

1. The reading level and assumptions of technical knowledge by the Court and Dierauf text indicated that it probably was written at a level higher than that of the average technical school student who has had only one year of high school math and no high school physics. One of the Advisory Committee members, Mr. James R. Johnson of North Central Technical Institute (Wausau, Wisconsin), attempted to use the text for his physics course in the fall of 1976 and verified (Appendix D) that it was above his students' capabilities.

2. The first 16 basic concepts covered in the text were judged by the Advisory Committee and the Technical Consultant (Dr. Leno S. Pedrotti, Chairman, Physics Department, U.S.A.F. Institute of Technology) not to be appropriate concepts for teaching within the first year of a technician curriculum. Rather, the following twelve concepts were selected as appropriate and "Matter, Units and Measurements" was determined to be a prerequisite for any and all modules.

"Force and Forcelike Quantities" -
"Work and Energy" -
"Rate" -
"Momentum" -
"Resistance" -
"Power" -
"Potential and Kinetic Energy" -
"Force Transformation" -
"Energy Transformation" -
"Vibration and Waves" -
"Time Constant" -
"Radiation" -

} Concept Modules.

For these reasons, the TERC-SW Project Director, in collaboration with the Technical Consultant, decided that TERC-SW should prepare 12 concept modules according to the titles shown above. These concept modules, averaging between 30 and 35 pages in length, would be used in lieu of the Court and Dierauf text to introduce concepts. The concept modules would be written at a proper student level and would avoid unusual terms and phrases coined by the Court and Dierauf text (e.g., "inertance").

B. MODULE DEVELOPMENT

Module development began in this project with one of the assigned team members preparing a matrix of the four energy systems for each concept (Appendix E). Under each energy system, physical applications were listed in basic terms to provide review matter from which the Advisory Committee could make module title selections. A matrix of this kind for each concept, with listed applications, enabled the Advisory Committee members to move applications from one concept to another, to combine applications into more meaningful groupings, and to fill voids and correct overlaps.

Once a module title was identified it was transferred to a Module Recommendation Form #CS5-77 (Appendix F). TERC staff, in consultation with the Committee, prepared a sample listing of the recommended items

and laboratory procedures each module should contain. This listing was prepared primarily to get each author off to a right start and onto a planned track. Very early in the program it was found that, with only the title information available, authors had difficulty drafting modules.

To obtain expertise, authors were selected from industry, two-year technical schools and four-year colleges. A high percentage of the original authors had written for TERC-SW on previous projects, those who were new had to submit samples of related written work for approval. Once an author was selected to write a particular module (or group of modules with similar applications) an agreement was made for payment and the following documents were sent to him (Appendix F):

- Cover letter.
- Copy of concept module to which author's application module(s) would apply.
- Letter of explanation of previous problems, assistance in understanding TERC system, and further explanation of the module segments.
- List of module recommendations, Form #CS5-77.
- List of modules written to date, with summary of each.

Upon receipt of the above, an author would prepare an outline and a set of module objectives, which were submitted to TERC for review and approval. This step assisted the author and TERC in controlling the evolution of each module in accordance with the total project plan and requirements.

Once an outline was approved, the author was released for the next step: to draft the module and submit it to TERC for review and approval. Upon receipt at TERC, the draft was checked for completeness, edited, revised, retyped if necessary and illustrated. A copy was submitted to the team of editors for educational and technical review. Meanwhile, TERC staff prepared laboratory materials lists and tested laboratory procedures prescribed for the module. Upon receipt of these edits, copy was revised in accordance with editors' comments, then retyped and re-illus-

trated (if required) into a final format. Revisions to the procedures were combined with the editors' corrections for final typing and duplication in preparation for school use.

Form #CS5-78 (Appendix F) provided TERC staff and Committee members with evaluation criteria for selection of UTC application modules.

To track production of 130 modules in various stages of completion, three important instruments were used by TERC.

- A master control schedule board was constructed, with modules listed by number and title (down the left-hand side) and contract time span divided into weekly intervals across the top. A series of code symbols was used for such events as -
  - Date module required.
  - Date module received.
  - Date module typed.
  - Date module edited.
  - Etc.

  Each module's progress and status was annotated onto the line corresponding to that module. This board enabled staff members to ascertain the status of each module relative to dates and schedules. Also, overall schedule status of the project was continually apparent and problem areas were highlighted, which allowed for corrective action before the schedule could be deformed.
- A flow chart for UTC modules (Form #CS6-78, Appendix F) showed key actions to be taken by TERC staff. As a module was identified, this chart - which standardized actions - aided immeasurably in avoiding errors and omissions.
- A UTC Module Assignment Plan (Form #CS7-78, Appendix F) was originated when a module title was identified and an author assigned. It became a "traveler," at-

tached to each module, going wherever the module went as it moved through the TERC module development process. Also, it keyed quality-control check points for module compliance to schedules and specification requirements.

C. INSTRUCTOR'S GUIDE

At an Advisory Committee meeting, members unanimously agreed that a document was needed to explain the what, why and how of UTC physics. It was to be a most important aid to any school interested in implementing UTC, but not as a "sales" document for UTC.

This request was reinforced by findings of TERC staff while visiting schools that were using UTC. It was noted that problems had arisen when instructors were unable to explain underlying concepts and energy interactions characteristic of UTC. A Unified Technical Concepts Instructor's Guide was developed to fill this need.*

In this document the philosophy that guided module development was presented briefly to provide an instructor (who keys the success or failure of these materials) with a UTC indoctrination. Key words, defined to establish a working vocabulary, provide a more valid understanding. Specific design features, including energy systems, of concept and application modules were emphasized and illustrated through example modules and descriptive charts. All of which provided a background of information against which suggestions for successful implementation of UTC was presented.

The Instructor's Guide has been critiqued by physics instructors in two- and four-year institutions, as well as scientists and industrial engineers. It represents a compendium of information needed by instructors

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* Copies of this Guide are available from the Office of Education or from TERC-SW; see title page for appropriate addresses.

who use UTC modules; however, it will be subjected to final revision prior to the completion of Phase II.

D. EXPERIMENTAL USE OF MODULES

Instructional materials cannot be developed in a vacuum; they must be designed for and used by an intended audience. UTC was developed for students in postsecondary technical schools and inservice technical training programs. It was hoped that several goals would be realized as a result of student use of the UTC modules. Included among these were the following:

- Determination of specific needs for new modules as the various technologies used existing materials and requested other titles.
- Checkout of the laboratory sections under classroom conditions for 1) level of difficulty and 2) appropriateness.
- Development of realistic time frames for module completion.
- Formulation of an approximate idea of the number of modules that can be covered in a given time frame.
- Revelation of student reactions to the UTC approach and to the modular design of materials.
- Determination of which modules were selected by instructors with students from various technologies.

The evolutionary nature of the UTC modules and limited test sites precluded rigorous field testing procedures. Consequently, a formative approach for experimental use of materials was selected. Close contact was maintained with instructors and their students (via instructor and student critiques). Many of their suggestions were immediately incorporated, which resulted in significant increase in useability and decrease in production costs.

Three schools initially agreed to participate by using the UTC modules in their physics programs:

- Site A. North Central Technical Institute (NCTI), Wausau, Wisconsin (a two-year technical school serving central Wisconsin and the mid-west).
- Site B. Camden County College (CCC), Blackwood, New Jersey (a two-year community college with technology and skills programs).
- Site C. Texas State Technical Institute (TSTI), with campuses in Waco, Harlingen, Amarillo and Sweetwater, Texas. (The physics department at Harlingen elected to use the modules on a limited basis).

Site A (NCTI) is a progressive technical school with seventeen associate degree programs and seventeen vocational diploma programs covering a wide spectrum of technician training. A group of 47 Residential Design students was selected to use the UTC modules to satisfy their need for a basic physics course. The time frame for the course was 2 hours of lecture and 2 hours of laboratory each week for one semester.

The instructor at North Central Technical Institute had 2 years of industrial experience and 26 years of teaching experience; however, because of institutional scheduling, he was not the anticipated instructor and consequently received very limited exposure to UTC before being asked to teach it. The previously selected instructor had chosen the modules found in Appendix G. Because the students were involved in structural design, a concentration of mechanical and thermal modules was selected relevant to their specialty.

Results indicated the following in relation to the desired objectives:

- Due to the specificity of the technology, several suggestions for additional modules were made, including more application modules concerning "R" factors and heat loss.
- It was noted that the laboratory sections in the concept modules were not well suited for student exper.-

ments and probably should be used only as demonstrations.

- Some modules were taking more study/classroom/laboratory time than had been anticipated. Concept modules were consuming from 6 to 9 hours when the students were doing each laboratory exercise; application modules were taking from 1 to 3 hours.
- By converting the laboratory sections of the concept modules to demonstrations only, the time required to complete each concept could be reduced substantially. Also, some suggestions were made for equipment substitutions in the application modules, which facilitated these experiments.
- Students at NCTI seemed only mildly impressed by the UTC approach. Only 30 of the 47 students indicated favorable responses to questions about UTC. This student attitude reflected, somewhat, the lack of indoctrination of the instructor.
- The selection of modules for this technology provided a guide or exemplary selection of modules for others teaching UTC to Residential Design students.

Site B (CCC) is a community college serving postsecondary educational needs of Camden County and the greater Philadelphia area. Thirty-six areas of study are offered, including two-year technical programs for those wishing early employment in chosen fields.

At CCC a class of 20 Opthalmic Science students were provided the UTC materials. Many of these students were college graduates seeking retraining for entry into a more dynamic job market. This class met weekly for 3 hours of lecture and 3 hours of laboratory through a 15-week semester.

The instructor at CCC, who had 15 years of teaching experience, had joined the UTC instructional team in the Fall of 1976. Consequently, he

had opportunity to become well acquainted with the UTC philosophy. His selection of modules for this group of students is reflected in Appendix G. Because these students were to have continued work in subsequent physics classes, the modules selected provided a more thorough grounding in all phases of physics.

Results from Site B relative to the indicated objectives were as follows:

- Few new titles were recommended but it was discovered that the sequence of the concept modules could be varied, which provided new insight into the proposed order of presentation.
- In general, the laboratory sections seemed to be adequate for instructor and students; however, some suggestions arose, such as adding areas (extra problems or questions) that students could respond to and by which their thought processes could be challenged concerning module content.
- As at Site A, the time span for module completion was longer than anticipated for many of the same reasons listed. An added problem was the use of a few supplementary experiments to teach areas not covered by UTC but traditionally covered by the instructor.
- Time data indicated that by presenting the laboratories (at the ends of the concept modules) as demonstrations, and by selecting an average of five application modules for each concept, a total of six concepts and related applications could be covered in a semester.
- The CCC students had an overwhelmingly positive reaction to the modularized UTC materials: nineteen of twenty responded favorably to questions concerning UTC.

- As at Site A, module selection (Appendix G) provided a model for those teaching physics to Opthalmic Science students.

Site C (TSTI) included only a partial test of the UTC material. Scheduling problems interrupted the trial, but additional use is scheduled for the 1978-1979 school year. TSTI is a two-year technical school with four campuses serving much of Texas with its 34 technical programs of study. Twenty-six Electronics Technology students were given the UTC modules during a portion of their physics course which met for 2 hours of lecture and 3 hours of laboratory each week for 11 weeks.

The instructor using the material at the Harlingen, Texas, campus had 8 years of experience and had worked closely with the UTC project for over a year. Also, he had authored several UTC modules early in Phase I. Because of previously mentioned problems, only the first seven concepts were used (Appendix G). As a result they do not represent an accurate example of modules that could be selected for Electronics Technology students.

Even though only limited use was made of the UTC material, some feedback was gained concerning the objectives, including the following:

- No new module titles were recommended but minor changes were noted in the appropriate concept modules.
- As with the other schools the laboratory exercises in the concept modules did not present an adequate challenge for the students.
- Similar time problems were experienced (as at Sites A and B) in attempting to use the laboratories as student-oriented procedures.
- The interrupted schedule did not allow accurate data collection.
- Indications were that a majority of the students approved of UTC. Once the idea of the unifying approach

was made clear to the students they readily appreciated the modules and unique approach to physics.

- The instructor indicated an initial problem of students having difficulty understanding UTC and that some of them did not grasp the significance of UTC until they reached Concept Module 3-0.
- As previously stated, this curriculum did not accurately represent the physics needs of Electronics Technology students.

Several important suggestions were made (during the experimental use of materials) by instructors, students and the UTC development team. One was the need for an instructor's guide that would detail the UTC philosophy and teaching strategies for those unfamiliar with the approach. Classroom aids also were requested, mostly in the form of diagrams or charts to summarize each concept and its energy systems. These aids would serve as constant reminders of the unifying approach in each concept.

An important time frame was realized, as previously described, which allowed the development of a rule of thumb: each semester should consist of about six concept modules, with an average of five application modules with each concept.

Minor errors, annotated on modules by teachers, were screened and their systematic elimination was undertaken as received.

Individual suggestions for specific changes in modules are too numerous to include; however, a few general format modifications incorporated, which have improved the materials and made them more usable, include:

- A reduction of module bulk by 26%.
- A reduction in type spacing, which incurred a 20% savings in paper.
- Inclusion of broad margins to encourage students to take notes.

It should be noted that new application modules are to be added as UTC Phase II proceeds. In further experimental use, schools will select different sets of UTC modules, tailoring curricula content to specific needs of students. As a result, many different modules will be used and important feedback will be accumulated, which will improve usability even more. Phase II will also provide an opportunity to test changes recommended in Phase I. (Feedback resulting from the use of modified modules, in Phase II, should indicate the degree of improvement over the original modules.)

Phase I indicated feasibility of UTC use in industrial settings for training new hires and in employee upgrading programs. As a test of this theory, plans made in Phase I will result in modules being used at the Los Alamos Scientific Laboratory (Los Alamos, New Mexico) during Phase II.

E. DISSEMINATION

A pamphlet (Appendix H) was developed to provide a synopsis of the UTC program and summarize the content of developed and developing materials. Interested schools and individuals have been given the pamphlet to explain the rationale of UTC (reasons for variance from traditional physics) and to provide them with a list of specific UTC module titles, and facts concerning the source and availability of UTC modules.

Displays of UTC modules, pamphlets and presentations have been made at four national and international locations:

- American Association of Physics Teachers, meeting in San Francisco, California - display booth (January 23-25, 1978).
- American Association of Physics Teachers, meeting in Chicago, Illinois - paper presented entitled, "A Unified System of Physics for Vocational/Technical Students," by TERC staff member (February 6-9, 1977).
- American Association of Physics Teachers, meeting in London, Ontario, Canada - paper presented entitled,

"Teaching More Physics in Less Time," by TERC staff member (June 14-17, 1977).

- American Technical Education Association, workshop held in Memphis, Tennessee - paper presented entitled, "Technicians for Energy Technologies in the Third Century," by TERC UTC Project Director (March 24-26, 1977).

As a result of this exposure, hundreds of inquiries have been received, including the 84 organizations and institutions (Appendix B) that have submitted serious requests for and have received information about UTC programs.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

Two specific conclusions and three significant recommendations, drawn directly from the work done in this project, are offered below.

A. CONCLUSIONS

The overall purpose of this grant effort was twofold:

- To reorganize physics into interdisciplinary concepts by using practical applications to demonstrate analogous relationships between phenomena that occur in electrical, mechanical, thermal and fluidal systems.
- To design, develop, implement, evaluate and revise an instructional delivery system. This system would consist of modular instructional materials that could be grouped in such a way as to provide technical physics courses tailored to the needs of two-year, postsecondary curricula for preparing engineering technicians. These curricula would cover ten or more specialty fields.

1. Reorganization

The first objective represents an awesome task; in many ways greater and more comprehensive than originally anticipated by the Project Director. Many attempts at this reorganization were begun before a framework could be established that was palatable to the TERC-SW staff, the Technical Consultant and the participating schools. The unification principles in physics are most strongly evident in concepts two (Force and Forcelike Quantities) through eight (Potential and Kinetic Energy); and, in concept thirteen (Radiation), the four analogous energy systems are abandoned in favor of examples in electromagnetic and particle radiation. This lack of complete order, however, is also clearly evident in more traditional approaches to physics, demonstrating the fact that phys-

ical phenomena are not confined to isolated systems, but are heavily interdependent.

Although the reorganization is not completed (and, no doubt, will undergo some changes during the course of development in Phase II), it is judged by students, faculty and many in the engineering and physics community to be reasonably successful. Acceptance by these groups is deemed absolutely essential since adoption of this material at schools would represent a clear preference over many other traditional and, consequently, more "comfortable" approaches.

2. Instructional Delivery System

The successful accomplishment of the second task is measurable and apparent, even at this early stage. The 130 modules (Appendix I) completed in this project have been selectively tested in classrooms; the materials and the delivery system have been evaluated and revisions have been made where appropriate and needed.

This project has been exemplary of educational research at its best - an innovative idea that showed promise was funded under the flexible conditions of a grant: when early research indicated that original assumptions were incorrect, the project efforts and approach were altered to achieve the basic tasks of the project; there is mounting evidence that results of the research will bear fruit in terms of significant usage of the project deliverables in the next two to five years.

B. RECOMMENDATIONS

Condinued module development, testing, evaluation and revisions will be accomplished during the second phase of this project. At the conclusion of the second phase, a complete, tested package of instructional materials and a program planning guide will be available. But, a project that is as apparently successful and useful as this one inevitably reveals several recommendations for additional or related work.

1. Self-Paced Labs

Flexibility for tailoring UTC to support various technical curricula and simplification of the process of scheduling labs would be

greatly enhanced if the application modules were converted into self-paced laboratories.

If this conversion was made, students from various technician programs could attend a single class; during the lab periods, students of one technical specialty could receive selected application module labs and students in the same class, in another technical specialty, could work on different lab assignments. Self-paced labs would allow this procedure without the need for instructors and lab aides for each technical specialty group.

2. Dissemination

Extensive efforts should be supported to disseminate these materials on as broad a basis as possible. Controlled dissemination activities are especially important for these materials because faculty understanding, attitude and approach are vital during the first year of teaching UTC.

3. Needs Survey

The need for interdisciplinary technicians is increasingly evident in areas such as building and equipment maintenance, energy-related technologies, computers, photocopy machines and research and development laboratories. In fact, the Project Director anticipates that the "new generation" of technicians in the next decade will need to have broad, interdisciplinary, backgrounds with a minimum of specialization prior to employment. This speculation needs to be verified by employer surveys, and a complete curriculum should be designed and developed. A heavy first-year course load in UTC would be ideal for this kind of curriculum.

APPENDIX A

UTC (Phase I) Advisory Committee

ADVISORY COMMITTEE - UTC PHASE I

PARTICIPANT	PRIMARY ROLE
Mr. Daniel M. Hull, Chairman General Manager TERC-SW Waco, TX	UTC Project Director.
Mr. Edward J. Dierauf Instructor of Applied Technologies City College of San Francisco San Francisco, CA	Inactive status since October, 1976.
Mr. Oscar Hinojosa Manager of Curriculum and Instruction Texas State Technical Institute Harlingen, TX	Administrator/Curriculum Specialist.
Mr. Dwain Ingram Technical Physics Instructor Texas State Technical Institute Waco, TX	Writer.
Mr. James R. Johnson Technical Science Instructor North Central Technical Institute Wausau, WI	Field Testing/Writer.
Mr. Carl Lansford Technical Science Instructor Texas State Technical Institute Harlingen, TX	TERC Staff Member - Sept., 1976, through July, 1977. Field Testing/Writer.
Mr. Herb Naylor Instructor, Engineering Technologies City College of San Francisco San Francisco, CA	Inactive status since October, 1976.
Dr. Leno Pedrotti Chairman, Department of Physics Dayton, OH	Chief Technical Consultant/Editor.
Dr. John D. Pierson Manager of Instructional Personnel Texas State Technical Institute Waco, TX	Consultant/Writer.
Mr. James F. Schon Chairman, Engineering Technologies City College of San Francisco San Francisco, CA	Inactive status since October, 1976.
Mr. Fred Seeber Associate Professor of Physics Camden County College Blackwood, NJ	Field Testing.
Mr. Vernon Woolf Associate Project Director TERC-SW Waco, TX	UTC Associate Project Director.

APPENDIX B

Schools and Organizations Indicating Interest

in Implementing UTC Programs

As of June 30, 1978

Pasco Scientific Co.
Flanders, NJ

Thornton Associates
Waltham, MA

Grand Rapids Junior College
Grand Rapids, MI

Campolindo High School
Moraga, CA

Santa Rosa High School
Santa Rosa, CA

University of Texas
El Paso, TX

San Jose City College
San Jose, CA

Los Angeles Trade-Tech College
Los Angeles, CA

Cleveland State Univ.
Cleveland, OH

U.S. Coast Guard Academy
New London, CT

Eureka College
Eureka, IL

Harvard School
North Hollywood, CA

Gallaudet College
Washington, DC

University of Minnesota
Minneapolis, MN

California Polytechnic
San Luis Obispo, CA

Midwestern State University
Wichita Falls, TX

University of San Francisco
San Francisco, CA

West Virginia University
Morgantown, WV

College of Eastern Utah
Price, UT

Washtenaw Community College
Ann Arbor, MI

John Abbott College
Beaconsfield, Quebec

Grossmont College
El Cajon, CA

University of Nebraska
Lincoln, NE

Sierra College
Rocklin, CA

Florida State University
Tallahassee, FL

San Joaquin Delta College
Stockton, CA

College of St. Thomas
St. Thomas, MN

Palisades High School
Pacific Palisades, CA

College of Marin
Kentfield, CA

Bay City High School
Bay City, TX

Rensselaer Polytechnic Institute
Troy, NY

Modesto Junior College
Modesto, CA

Hudson Valley Community College
Troy, NY

Hamline University
St. Paul, MN

New England College
Henniker, NH

Oregon Graduate Center
Beaverton, OR

Glenbard East High School
Lonbard, IL

Scottsdale Community College
Scottsdale, AZ

Sherwood High School
Sandy Spring, MD

Oklahoma State Tech
Oklahoma City, OK

Divine Word College
Epworth, IA

College of the Pacific
Stockton, CA

San Mateo County Office of Education
Redwood City, CA

Abilene Christian University
Abilene, TX

Chuck Potter
Cypress, TX

Missoula Vocational Technical Center
Missoula, MT

Deerfield Academy
Deerfield, MA

Dallas Independent School District
Dallas, TX

Walter Stewart
Los Alamos, NM

Bradley University
Peoria, IL

St. Mark's School
Dallas, TX

W.R. Harper College
Palatine, IL

University of Northern Iowa
Cedar Falls, IA

Prairie State College
Chicago Heights, IL

Winona State University
Winona

Castleton State College
Castleton, VT

Florissant Valley Community College
St. Louis, MO

Martin Van Buren High School
Queens Village, NY

Foster Radiation Lab
McGill University
Montreal P.Q. Canada

Elgin Community College
Elgin, IL

University of the Pacific
Stockton, CA

Allegheney College
Meadville, PA

Pima Community College
Tucson, AZ

Mankota State University
Mankota, MN

Lewis & Clark Community College
Godfrey, IL

Joliet Junior College
Joliet, IL

Eastern New Mexico University
Portales, NM

University of Wisconsin - Stout
Menominee, WI

College of St. Benedict
St. Joseph, MN

Central State University
Edmond, OH

University of Puerto Rico
Rio Piedras, PR

University of Texas at El Paso
El Paso, TX

Beloit College
Beloit, WI

West Kentucky University
Bowling Green, KY

University of Minnesota
Minneapolis, MN

University of Colorado
Colorado Springs, CO

Eastfield College
Mesquite, TX

Rutgers University
Piscataway, NJ

University of Michigan - Dearborn
Dearborn, MI

Western Washington University
Bellingham, WA

Iona College
New Rochelle, NY

Milwaukee Trade & Technical High School
Milwaukee, WI

APPENDIX C

Example Concept Module:

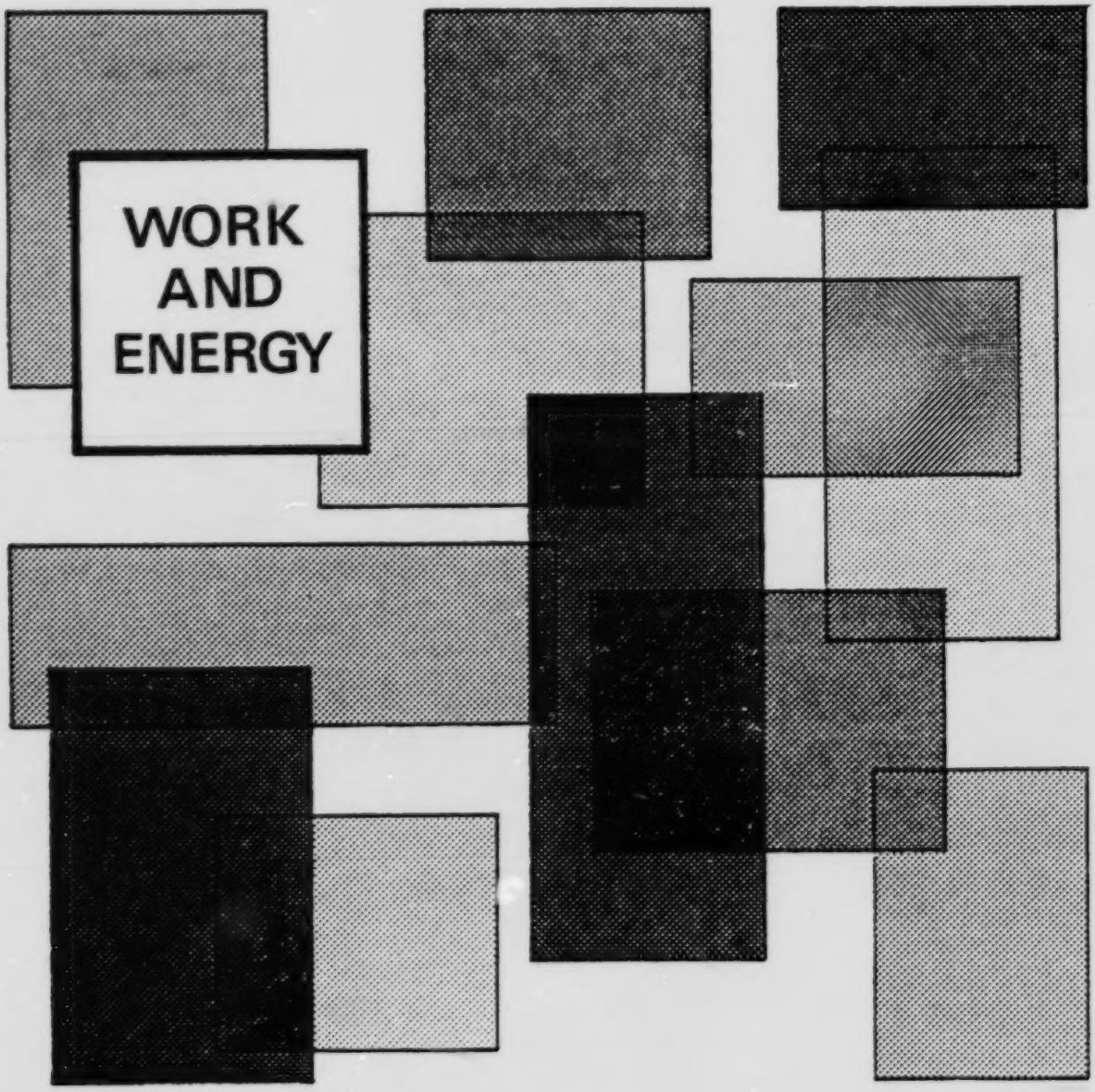
3-0, "Work and Energy"

UTC

UNIFIED TECHNICAL CONCEPTS

CONCEPT MODULE 3-0

WORK AND ENERGY



TERC-SW

Technical Education Research Center – Southwest

UTC

UNIFIED TECHNICAL CONCEPTS

PRELIMINARY DRAFT - NOT FOR SALE

PRIVATELY CIRCULATED SOLELY FOR REVIEW AND EVALUATION

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TERC-SW

TECHNICAL EDUCATION RESEARCH CENTER - SW

4201 LAKE SHORE DRIVE, SUITE 111

WACO, TEXAS 76710

PREFACE

Why UNIFIED PHYSICS?

Modern industries have an increasing need for technicians who are able to install and maintain complex production equipment. Maintenance of this equipment often requires a high degree of competence in hydraulic, pneumatic, thermodynamic, or optical subsystems, as well as in mechanical and electrical components. The technician must understand the component parts, but also, he must have some understanding of the integrated system.

Institutions seeking to develop modern vocational training programs have often recognized a need for one or more Physics courses to teach physical principles. UNIFIED TECHNICAL CONCEPTS is a modularized system of instruction which seeks to fill this need in a special way.

UNIFIED TECHNICAL CONCEPTS explains how energy is stored, transferred, and controlled. Rather than studying mechanics, fluids, heat, and electricity separately, a unifying concept such as "rate" or "resistance" is presented. Applications of the unified concept to each of the four areas are shown. This approach takes advantage of the analogies which exist among these areas in order to economize the learning process. Students are able to learn general formulas which replace many specialized formulas they would otherwise have to memorize. Furthermore, this UNIFIED approach helps technicians understand relationships between components in the complex equipment.

Careful selection of CONCEPT MODULES and APPLICATIONS MODULES from the UTC materials makes it possible for institutions to prepare "tailor-made" courses which are relevant to each particular vocation. Every module contains "hands-on" laboratory experiences and makes use of practical equipment that is meaningful to the student. Module 1.0, Matter, Units, and Measurement prepares the student for understanding the Concept modules (2.0 - 13.0)

The UNIFIED TECHNICAL CONCEPTS being developed in this program are:

2.0 Force and Force-Like Quantities
3.0 Work and Energy Systems
4.0 Rate
5.0 Momentum
6.0 Resistance
7.0 Power
8.0 Potential and Kinetic Energy
9.0 Force Transformers
10.0 Energy Transformers
11.0 Vibrations and Waves
12.0 Time Constants
13.0 Radiation

Daniel M. Hull, Project Director
Technical Education Research Center-SW
4201 Lake Shore Drive, Suite 111
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ABOUT UNIFIED TECHNICAL CONCEPT (UTC) MODULES

The UTC modules are being developed by TERC-SW for use in two-year post secondary technical institutions preparing technicians for employment. These instructional modules will also be evaluated for their usefulness to industries for updating their employees in company-sponsored training and to laboratory texts in engineering schools. The modules are being written by technical instructors and physicists and will be tested with students. Each module contains the following elements.

Introduction, which identifies the topic and often includes a rationale for doing the exercises.

Objectives, which clearly tell the student what he is expected to know for satisfactory completion. The objectives are stated in terms of action oriented behaviors and which include such action words as *operates*, *measures*, *calculates*, *identifies*, and *defines*, instead of words with many interpretations such as *know*, *understand*, *learn* and *appreciate*.

Discussion, which presents the background theory and techniques supportive to the objectives of the lesson. An understanding of the discussion requires prior math background in high-school algebra. Any other prerequisites to understanding the material will be stated at the beginning of each module.

Materials, which identifies the equipment required to complete the laboratory procedure. A complete equipment list and specifications can be supplied upon request.

Procedures, which is the experiment section or "hands-on" portion of the module. It includes step-by-step instructions. The experiments are designed to reinforce student learning, and data sheets for each experiment are provided in each module.

Exercises, which are included for the purpose of reviewing and reinforcing the points covered in the exercise.

Reference Materials, which are included as supplementary reading/reviewing for the student.

INTRODUCTION

Years ago, most work accomplished was through physical efforts of men and animals. Today, less than three percent of the energy required by industry is provided by muscular exertion. Modern industries are highly mechanized. Even many machines are controlled by mechanical devices rather than by men. Work has become a technical term, and scientists and technicians must define it in a technical way. In this module, work will be defined, and various applications of work in the fields of mechanical, fluid, thermal and electrical energy will be shown. Energy will also be defined, and units for work and energy will be introduced.

PREREQUISITES

The student should have completed Concept Module 2-0, "Force and Forcelike Quantities," and should have completed one year of basic (high school) algebra.

OBJECTIVES

To complete this module, the student should be able to:

- Define the following concepts and express their basic units in both SI and English systems of units.
  - Work and energy in mechanical translational systems.
  - Work and energy in mechanical rotational systems.
  - Work and energy in fluid systems.
  - Work and energy in heat systems.
  - Work and energy in electrical systems.
- Explain how work and energy play the same roles in mechanical, fluid, heat and electrical systems.
- Define energy in such a way that it is distinguished from work.

- Given forcelike quantities and distances moved, compute values for energy and work in mechanical, fluid, thermal and electrical systems.

Recall that, in Module 2-0 on forces, it was shown that a forcelike quantity applied in a mechanical, fluid, thermal or electrical system causes movement. If no force, torque, pressure, temperature difference or electromotive force is applied, there will be no movement in the system. When a forcelike quantity is present, displacement or movement will result. The combination of a forcelike quantity and a displacementlike quantity is called work. A general formula for the unifying concept of work is given in Equation 1.

$$\text{Work} = \text{forcelike quantity} \times \text{displacementlike quantity} \quad (1)$$

This general formula can be used in each system with the exception of the thermal system.

MECHANICAL SYSTEM

MECHANICAL WORK, TRANSLATIONAL

A man is shown in Figure 1 lifting a 200-lb weight to a height of six feet. Obviously, work has been done in lifting the weight. The man has lifted the weight to a specific distance, and the amount of work he has done can be found by multiplying the forcelike quantity and the displacement (distance weight was lifted from the ground). This definition is given by Equation 2.

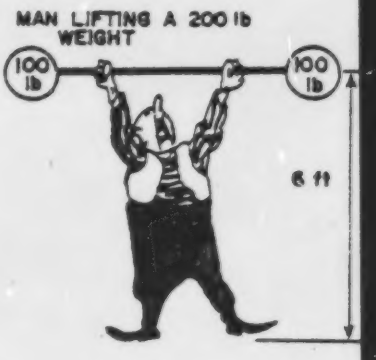


Fig. 1

$$\text{Mechanical work (translational movement)} = \text{force} \times \text{displacement} \quad (2)$$

According to this definition of work, the object must be moved (and moved in the direction of the force), or no work is accomplished. The man can tug and strain at the weights, but if he does not manage to lift them, no work has been done. How tired he becomes is not involved in the definition of work! Forces that are not effective in producing displacement (movement) are not doing work. This type of situation is illustrated in the pushing of a lawnmower as (Figure 2). Since the handle of the lawnmower is at an angle, part of the force applied when

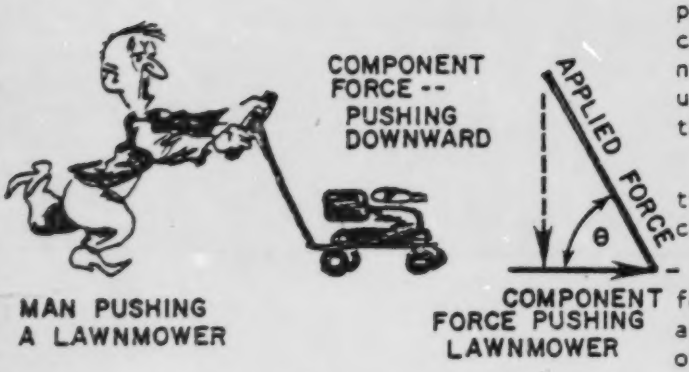


Fig. 2

pushing the mower is a downward force. Because the downward part of the force does not cause movement, it does not accomplish useful work. Only the force parallel to the ground contributes to work.

Resolution of forces involved in this type of problem will be shown in an applications module.

Common units for mechanical work are foot-pounds (ft-lb) in English (FPS) units, and Joules (J) in the International System of Units (SI). One Joule of work is the same as one newton-meter (N-m) of work. The units Joule and newton-meters can be interchanged as needed. Conversion factors are given in Table 1.

TABLE 1. CONVERSION FACTORS

1 Joule	=	1 Newton-meter
1 Joule	=	0.738 foot-pounds
1 Joule	=	10^7 ergs
1 erg	=	1 dyne-cm

The unit "erg" is equal to a dyne-cm. It is used in the CGS system of units (centimeter-gram-second), and since it is a unit for a very small amount of work, it is not used in this module.

Energy is defined as capacity to do work. If 100 ft-lb of energy is available, in principle 100 ft-lb of work can be done. The quantity, as well as its units, is the same for both work and energy. Examples A and B show how problems involving mechanical work and energy can be solved.

MECHANICAL WORK, ROTATIONAL

In mechanical work involving rotation, the distance an object turns on its axis is determined by measuring the angle through which the object turns. Work is defined by multiplying torque by the angle of rotation. This definition is given by

EXAMPLE A: WEIGHT LIFTING

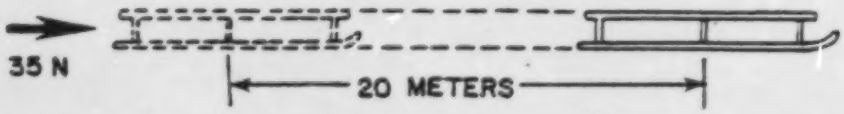
Given: A man (Figure 1) lifts a 200-lb weight to a height of 6 ft.

Find: Amount of work required.

Solution: Work = force x displacement
= 200 lb x 6 ft
= 1200 ft-lb.
Energy required = 1200 ft-lb.

EXAMPLE B: PUSHING A SLED

Given: A force of 35 newtons applied continuously to push a sled 20 meters.



Find: Amount of energy required.

Solution: Energy = work = force x displacement
= 35 N x 20 m
= 700 N-m = 700 J
Work = 700 J.

Recall: 1 J = 0.738 ft-lb

$\frac{0.738 \text{ ft-lb}}{1 \text{ J}} = 1.$

Work = 700 J x $\frac{0.738 \text{ ft-lb}}{1 \text{ J}}$ = 516.6 ft-lb.

516.6 ft-lb of work will be done.

Equation 3.

$$\text{Mechanical work (rotational movement)} = \text{torque} \times \text{angle of rotation.} \quad (3)$$

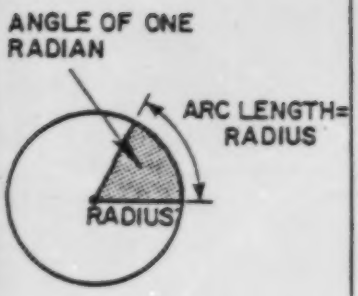


Fig. 3

An angle can be measured in degrees or in number of revolutions. However, a more convenient measure in radians is commonly used. In Equation 3, the angle must be expressed in radians. An angle of one radian is that angle that, if placed at the center of a circle, would enclose an arc length equal to the radius of the circle. The size of an angle of one radian is shown in Figure 3.

This angle of one radian is approximately 57.3°, but it is easier to remember an identity derived from the formula for the circumference of a circle. The circumference of a circle encloses an angle of 360°. Since circumference is found by multiplying 2 times π times radius, and one radius corresponds to one radian: 2π radians = 360°. This relationship, and another that results when both sides are divided by two, are shown in Table 2.

TABLE 2. CONVERSION FACTORS
2π radians = 360°.
π radians = 180°.

Since π radians = 180°, 1 radian = $180°/\pi$, or 1 degree = $\pi/180$. The radian is an angular measurement and is a dimensionless quantity having no units.

Mechanical work problems involving rotation are shown in Examples C and D.

FLUID SYSTEM

Work is accomplished when a pressure is applied to move a volume of fluid. The general formula, work = forcelike quantity x displacementlike quantity, takes the form shown by Equation 4 for the fluid system.

$$\text{Work}_{(\text{fluids})} = \text{pressure} \times \text{volume change}. \qquad (4)$$

The forcelike quantity in the fluid system (quantity that causes movement of the fluid) is pressure, and the displacementlike quantity is represented by the volume change in fluid.

As previously stated, there must be some movement in the system or work has not been done. Forty pounds of pressure in a tire is not work in itself, but work is done in putting the air into the tire. The volume change involved in the work would be the difference between volume of air under pressure in the tire

EXAMPLE C: WORK DONE BY A PULLEY

Given: A force of 70 pounds is needed to just turn a pulley 5 revolutions at a constant speed.

Find: Amount of work done by the pulley.

Solution: Work = torque x angle of rotation.
Since: 1 revolution = 360° = 2 π radians,

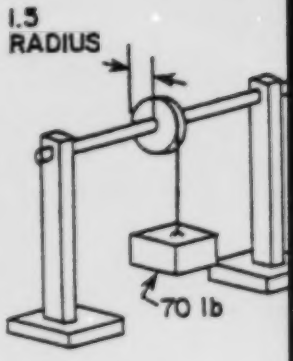
$$5 \text{ revolutions} = 5 \text{ rev} \times \frac{2\ \pi \text{ rad}}{1 \text{ rev}} = 10\ \pi \text{ rad.}$$

Recall (from Module 2-0):

Torque = force x lever arm
= 70 lb x 1.5 ft
= 105 ft-lb.

Work = 105 ft-lb x 10 π radians
= 105 ft-lb x 10 x 3.14 (Radians can be left off, since they have no units.)
Work = 4397 ft-lb.

Energy from this system could lift a one-pound weight to a height of 3297 feet, 3297 pounds to a height of one foot, or 32.97 pounds to a distance of 100 ft, etc.



EXAMPLE D: ENERGY STORED IN A ROTATING FLYWHEEL

Given: A heavy flywheel, 1.2 meters in diameter, rotates 484 degrees before stopping, while a braking force of 80 newtons is being applied at its outer edge.

Find: Amount of energy consumed in stopping rotation.

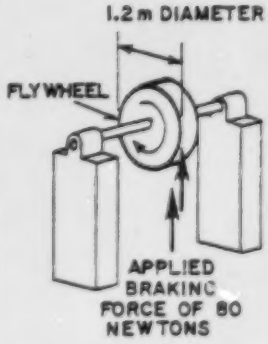
Solution: Since diameter = 1.2 meters, radius = 0.6 meters.
Energy consumed = work = torque x angle of rotation
Energy = force x lever arm x angle of rotation

$$= 80 \text{ N} \times 0.6 \text{ m} \times 484° \times \frac{\pi \text{ rad}}{180°}$$

Since π radians = 180°, $\frac{\pi \text{ rad}}{180°} = 1$.

Energy = 405.3 N-m.

Energy required to stop the flywheel is 405.3 N-m.

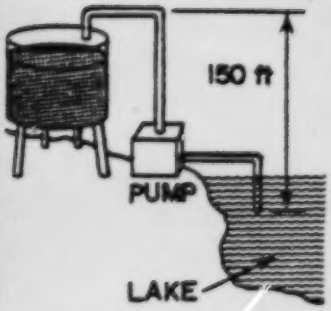


and volume the same quantity of air would occupy if released to the atmosphere.

Work done in filling a tire with air is stored, for the most part, in increased energy of the air molecules in the tire. A mechanic must exercise caution in filling an automobile tire (or tube) with air after repairing it. If the tire and wheel are not put together correctly, the tire can explode and cause serious injury. Businesses involved in changing and repairing large tires provide a heavy safety frame that holds the tire while it is being filled with air.

Work is done in moving fluids from one place to another. Example E shows how much work and energy are involved in filling a tank with water.

EXAMPLE E: WORK ENERGY IN FILLING A WATER TANK



Given: Water tank system of 500 cubic feet.

Find: Amount of energy required to fill it with water from the lake below.

Solution: Energy = work = pressure x volume displaced.

Recall:

$$\text{Density of water} = 62.4 \frac{lb}{ft^3}$$

Pressure = height x density (see Module 2-0)

$$\text{Pressure} = 150 \text{ ft} \times 62.4 \frac{lb}{ft^3}$$

$$\text{Pressure} = 9360 \frac{lb}{ft^2}$$

$$\text{Energy} = 9360 \frac{lb}{ft^2} \times 500 \text{ ft}^3$$

Energy = 4,680,000 ft-lb, or 4.68×10^6 ft-lb.

Units for work and energy in the fluid systems are the same as they are in the mechanical system. This module uses ft-lb in FPS units, and Joules (1 J = 1 N-m) in MKS units.

THERMAL SYSTEMS

In a thermal system application of the general work formula

- work equals forcelike quantity times displacementlike quantity - is less obvious than in mechanical and fluid systems. This is simply due to the somewhat "strange" nature of the displacement-like quantity in thermal systems. The forcelike quantity in thermal systems is temperature difference ΔT, and the displacementlike quantity is the quantity of heat that flows from high to low temperatures. How is "quantity of heat" represented? Clearly, quantity of heat as the displacementlike quantity in thermal systems is less natural than distance and angle in mechanical systems and volume moved in fluid systems. Although we shall not reproduce the reasoning here, quantity of heat can be represented as a displacementlike quantity by the product of mass of substance heated times specific heat of the substance. This product of mass x specific heat is also known as heat capacity. With this as a brief background, the work formula in thermal systems can be developed as follows:

$$\text{Work} = \frac{\text{forcelike}}{\text{quantity}} \times \frac{\text{displacementlike}}{\text{quantity}}$$

$$\text{Thermal work} = \Delta T \times \text{heat capacity}$$

$$\text{Thermal work} = \Delta T \times (\text{mass} \times \text{specific heat}). \qquad (5)$$

In thermal systems, the quantity of heat that flows is energy, and it is driven by the temperature difference. In essence, energy is actually the average increased motion of molecules in the substance, moving from higher to lower temperature regions. Thermal properties of different substances vary widely and depend intimately on molecular structure of the substances. Thermal properties are neatly summed up in two quantities - which are very useful - specific heat and thermal conductivity. Specific heat simply tells how many calories of heat energy are required to raise a unit mass of some substance a unit temperature difference. Water, for example, has a specific heat of 1 cal/g-C°, wood a specific heat of 0.42 cal/gm-C° and steel 0.115 cal/g-C°. Thermal conductivity is the rate of heat flow by conduction per unit area per unit temperature gradient. For example, water has a thermal conductivity of 1.43×10^{-3} cal/cm^2-C°, wood a thermal conductivity of 0.3×10^{-3} cal/cm^2-C° and steel 0.11 cal/cm^2-C°.

Specific heat is simply heat capacity per unit mass. Since

water has a high heat capacity - that is, an ability to soak up large amounts of heat energy at the expense of only a small increase in temperature - it makes an ideal coolant. That's why water is used as the coolant in most systems where considerable thermal energy is generated.

Thermal conductivity is related to rate of heat transfer by conduction. Consider the following common situation. We need to use a hammer that has been lying in the hot sun for a while. If we pick the hammer up by the steel head, we might well burn our hands; if we grasp the handle instead, we simply experience a warm feeling. Why? Both metal head and wooden handle are at the same temperature, so one is clearly not hotter than the other. But thermal conductivity of steel is over 1000 times that of wood, so the heat flows from steel to our hands much faster than from the wood, causing the "hand temperature" to rise much more rapidly when holding the steel head than when holding the wooden handle. So it's clearly a difference in thermal conductivity, not temperature, that makes the head feel hotter than the handle. For the same reason, a rug on the floor feels warmer than the bare floor on a cold morning, even though temperature of rug and floor are identical.

In SI units, quantity of heat is measured in calories (cal) or kilocalories (kcal). One calorie is the amount of heat required to raise one gram of water one degree Celsius. Since the calorie measures small amounts of heat, kilocalories (kcal) are often used to measure larger quantities. Measures of the heat values of foods, incorrectly given as calories in diet books, are actually kilocalories. For instance, bread that claims to have 60 calories per slice actually has 60 kilocalories per slice.

In English units, quantity of heat is measured in British thermal units (Btu). One British thermal unit is the amount of heat required to raise one pound mass of water one degree Fahrenheit. This unit is often used in the United States to measure cooling capacity of air conditioners or heating capacity of stoves. Table 3 lists some useful conversion factors.

TABLE 3: CONVERSION FACTORS		
1 Btu	=	252 cal
1 kcal	=	1000 cal
1 cal	=	3.09 ft-lb
1 Btu	=	778 ft-lb
1 cal	=	4.18 Joules

As explained above, work has the same units as quantity of heat energy. Work (or quantity of heat energy) can be determined by multiplying thermal capacity of a material (mass x specific heat) times change in temperature. This definition is restated in Equation 6.

$$\text{Work} = \text{mass} \times \text{specific heat} \times \text{change in temperature.} \quad (6)$$

Specific heats of numerous substances have been determined experimentally and can be found in tables of specific heats such as Table 4.

TABLE 4. SPECIFIC HEATS OF COMMON SUBSTANCES

Substance	Specific Heat
Air	0.24
Aluminum	0.22
Brass	0.091
Copper	0.093
Glass	0.21
Iron (steel)	0.115
Stone (average)	0.192
Tin	0.055
Water	1.00
Wood (average)	0.42

Specific heats are ratios, and the value is the same in either SI or English units. Units for specific heat are Btu/lb x °F, kcal/kg °C, or cal/g°C. Specifc heat of water was adopted as a standard because of its large heat capacity and availability.

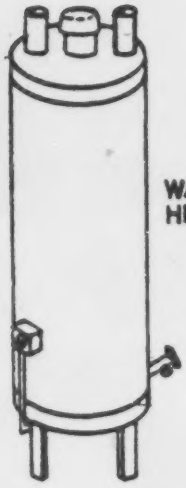
Use of the formula for work in the thermal system is illustrated in Examples F and G.

ELECTRICAL SYSTEM

In the electrical system, work done and energy stored or released are measured in Joules (J) and ergs (erg). The general formula for work takes the form shown in Equation 7.

$$\text{Work} = \text{potential difference} \times \text{charge moved.} \quad (7)$$

Potential difference, which is measured in volts (V), is the



WATER HEATER

EXAMPLE F: HEAT ENERGY IN A WATER HEATER

Given: 417 pounds (approximately 50 gallons) of water.

Find: Amount of heat energy required to heat water from 70° F to 130° F. Assume no heat loss in heating water tank or atmosphere ($1\ ft^3 = 7.48$).

Given: 417 pounds (approximately 50 gallons) of water. ($1\ ft^3 = 7.48$ gal.) ($1\ ft^3$ of water weighs 62.4 lb.)

Find: Amount of heat energy required to heat water from 70° F to 130° F. Assume no heat loss in heating water tank or atmosphere.

Solution:

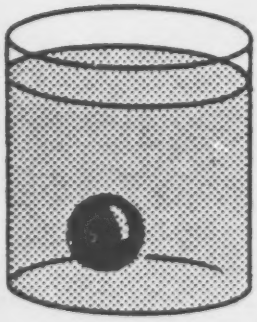
Energy = work = mass x specific heat x change in temperature

$$= 417\ lb \times 1\ \frac{Btu}{lb \times °F} \times (130° F - 70° F)$$

Energy = 25,020 Btu.

Energy required (assuming no heat loss) would be 25,020 Btu.

EXAMPLE G: HEAT ENERGY PROBLEMS



Given: A 25-kg brass ball at 100° C cooled to 30° C in a container of water.

Find: Amount of work done in heating the water. Assume no heat loss to container or atmosphere.

Solution: Work = mass x specific heat x change in temperature

$$= 25\ kg \times 0.091\ \frac{kcal}{kg\ °C} \times (100° C - 30° C)$$

Work = 159.3 kcal, or 159,300 cal.

A total of 159.3 kcal of heat was supplied to heat the water.

Given: Above answer represents a change of 40° in water temperature.

Find: Amount of water (g) in the container.

Solution: Work = mass x specific heat x change in temperature

$$159.3\ kcal = mass \times 1\ \frac{kcal}{kg\ °C} \times 40° C = Mass = \frac{159.3\ kcal}{\frac{kcal}{kg\ °C} \times 40° C}$$

Mass = 3.983 kg = 3983 g. This container has 3983 g of water in it if no heat is lost to the container.

forcelike quantity. Charge, which is measured in coulombs (C), is that substance in electrical circuits that is moved by a potential difference. Thus, charge is the displacementlike quantity.

A new charge of one coulomb represents 6,250,000,000,000,000,000 more electrons at the negative pole than at the positive pole. Since this number is so large, it is usually written 6.25×10^{18}. One Joule of work or energy in the electrical system is the amount of energy expended when one coulomb of charge is moved through a voltage difference of one volt. Table 5 gives useful conversion factors for electrical energy.

TABLE 5. CONVERSION FACTORS

1 Joule = 1 volt x coulomb.

1 coulomb = charge of 6.25×10^{18} electrons.

Examples H and I illustrate use of the formula for electrical work or energy.

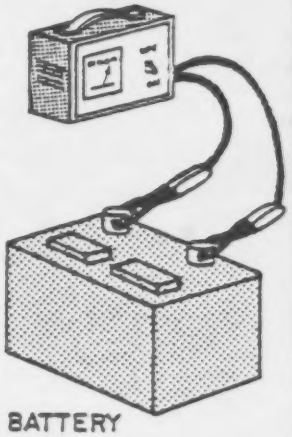
EXAMPLE H: ENERGY REQUIRED TO CHARGE A BATTERY

Given: A 6-volt automobile battery that stores 8000 coulombs of charge.

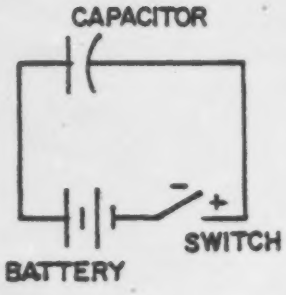
Find: Energy required to charge it.

Solution: Energy = work = potential difference x charge moved
= 6 V x 8000 C
Energy = 48,000 V x C = 4.8×10^4 J.

An energy of 4.8×10^4 Joules is required to charge the battery.



BATTERY



EXAMPLE 1: CHARGING A CAPACITOR

Given: A capacitor with 0.80 J of energy supplied to it by a 12-volt battery.

Find: How much the capacitor has been charged.

Solution: Energy = work = potential difference x charge
0.80 J = 12 V x charge
Charge = 0.80 J/12 V
Charge = 0.0667 J/V = 0.0667 C.

Since 1 Joule (J) = 1 volt (V) x coulomb (C), $\frac{1 \text{ Joule}}{\text{volt}}$ = 1 coulomb.

A charge of 0.0667 C is forced onto the capacitor.

Find: How many more electrons are on the negative capacitor plate after charging.

Solution: 1 coulomb = charge of 6.25×10^{18} electrons.

$$1 = \frac{6.25 \times 10^{18} \text{ electrons}}{1 \text{ C}}$$

$$0.0667 \text{ C} \times \frac{6.25 \times 10^{18}}{1 \text{ C}} \text{ electrons} = 4.17 \times 10^{17} \text{ electrons.}$$

Approximately 4.17×10^{17} more electrons are on one side of the capacitor than are on the other.

As evident, work and energy are concepts unifying each of the four energy systems discussed in this module. The student should first learn the general unifying formula for work. When the student understands how this general formula applies in the mechanical, fluid, thermal and electrical systems, the specialized formulas for each system will be easier to remember. Further, the student will begin to see that each of these energy systems is closely related to the others.

Storage of energy is an important concept that will be discussed in Module 8-0, "Potential and Kinetic Energy." In Module 8-0, energy will be classified as energy stored due to its position (potential energy) and as energy stored in motion (kinetic energy).

MECHANICAL SYSTEM, LINEAR WORK

MATERIALS

Mass (can be cardboard box with something heavy in it) approximately 10 kg.
Balance.
Meter stick.

PROCEDURE

In this experiment, the student is to calculate work done in lifting an unknown mass and placing it on a table.

1. Lift unknown mass from floor onto table (Figure 4).
2. Determine mass of object using a balance scale.
3. Measure distance object was lifted in placing it on table.
4. Fill in Data Table 1, calculating work done in lifting mass to table.

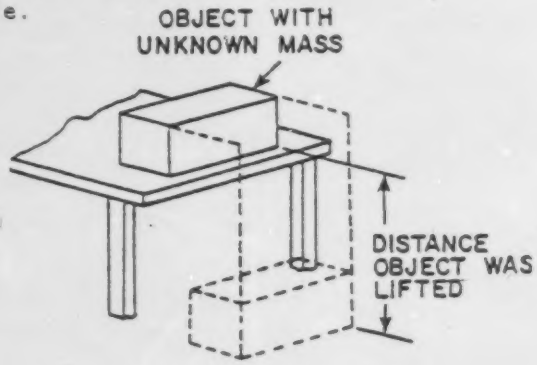


Fig. 4

DATA TABLE 1		
Mass of Object Lifted	Distance Object Was Lifted	Work Done Lifting Mass
		N-m
		J
		ft-lb

MECHANICAL SYSTEM, ROTATIONAL WORK

MATERIALS

Gyroscope (lab model or toy).
Pulley and bracket for table mount.
Micrometer.
50-g mass.
String.

PROCEDURE

Determine work done in spinning gyroscope illustrated in Figure 5.

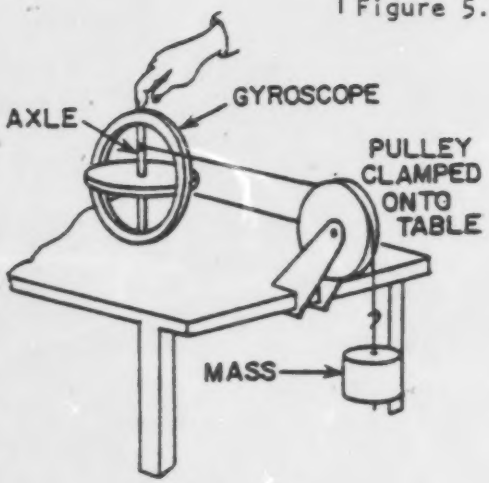


Fig. 5

1. Using a micrometer, measure diameter of gyroscope axle. Calculate radius of axle.
2. Count number of revolutions used in winding up string. Do not tie string to axle.
3. Hold gyroscope carefully while placing string across a pulley mounted on table. Suspend a mass of approximately 50 g on string so that, when string is released, weight will fall toward floor, applying a constant force on string. String should be completely unwound before weight strikes floor.
4. Fill in Data Table 2, calculating torque on axle and work done in spinning gyroscope wheel.

DATA TABLE 2

Axle		Number of		Mass on String	Force** on String (N)	Torque	Work
Diameter	Radius	Revolutions	Radians*				
_____ mm _____ m	_____ m			_____ g	_____ N	___ N-m	___ N-m

* Recall that 2 π rad = 1 revolution.
** Recall that 1 N = 0.102 kg.

FLUID SYSTEM WORK

MATERIALS

Rubber hose.
2 hose clamps.
Pressure gage (0-100 psi).
Jug (such as a mulk jug).
Beaker, graduated in liters.

PROCEDURE

In this experiment the student will determine work done in filling a gallon container from a water faucet.

1. Insert one end of a rubber hose on a pressure gage. Clamp other end of hose securely to water faucet. Turn on water fully and measure water pressure at faucet.
2. Fill jug with water from faucet.
3. Measure water by pouring it into a beaker graduated in liters.
4. Fill in Data Table 3, calculating work done in filling jug.

DATA TABLE 3

Water Pressure at Faucet	Volume of Jug	Work Done in Filling Jug
_____ psi _____ N/m^2*	_____ liter _____ cm^3** _____ m^3	_____ N-m _____ J

*1 lb/in^2 = 6895 N/m^2.
**1 liter = 1000 cm^3.

ELECTRICAL AND THERMAL SYSTEMS WORK

MATERIALS

Balance.
Small piece of thin copper wire, approximately 1 1/2 meters long (20 gage or equivalent).
6- or 12- volt storage battery.
Styrofoam plastic cup and block of styrofoam to use as a lid.
Two alligator clip leads for power source.
Voltmeter.
Thermometer (1° C graduations).

PROCEDURE

This experiment will combine electrical and thermal systems in one experiment. Electric potential will be supplied to a small thin copper wire immersed in a styrofoam cup filled with water. As charge moves through the wire, heat is generated.

1. Measure emf of battery or power source.
2. Measure mass of water in styrofoam cup on balance scale.
3. Record temperature of water in cup before power source is connected.
4. Form copper wire into a coil, being careful not to touch bare wires. Connect clip leads and immerse coil in water (Figure 6).
5. Connect power source. Keep voltage across wire small enough so that no boiling occurs. After temperature has increased about 10 degrees, disconnect all leads and record temperature.
6. Fill in Data Table 4, calculating heat energy supplied to water (calories) and electrical energy necessary to supply that heat energy.

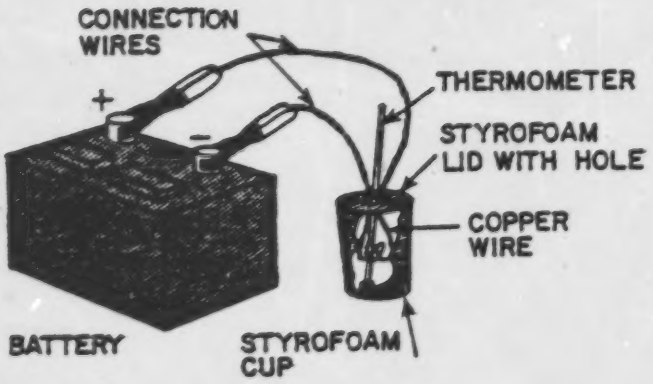


Fig. 6

DATA TABLE 4		
Mass of water in cup	_____	g
Beginning temperature	_____	°C
Final temperature	_____	°C
ΔT	_____	°C
Heat energy supplied (Equation 5)	_____	cal
Electrical energy used to supply heat*	_____	J
emf (from voltmeter)	_____	V
Charge transferred (Equation 6)	_____	C
Electrons transferred**	_____	electrons

*1 cal = 4.18 J.
**1 C = 6.25×10^{18} electrons.

The student should realize that more electrical energy was actually supplied than that needed to heat the water alone. Where is this additional energy consumed?

SELF CHECK

1. Define work and energy in each of the energy systems by completing the table on the next page. List units with each quantity.
2. Explain how work and energy play the same roles in mechanical, fluid, heat and electrical systems.
3. Explain the relationships between work and energy.
4. Solve the following problems:
   a. How much energy is required to slide a box a distance of 1500 km if force applied in the direction of motion is equal to 70 N?
   b. How much work is done in removing a nut from a bolt if

System	Work or Energy Units	Forcelike Quantity Units	Displacementlike Quantity Units
Mechanical (linear)			
Mechanical (rotational)			
Fluid			
Heat			
Electrical			

an average torque of 70 N-m must be supplied for 4 1/2 revolutions? How many ft-lb of work is this?

c. A pump consumes 13,000 J of energy when moving 18 m^3 of water under constant pressure. What pressure (N/m^2 and lb/ft^2) did the pump supply to the water?

d. An air conditioner is capable of providing an air pressure of 1/4 psi. How much energy is required to fill a room 20 ft x 30 ft x 8 ft with cool air?

e. How many calories of heat are required to raise the temperature of 500 g of copper from 20° C to 95° C? See Table 3.

f. If a 12-V (d.c.) electric refrigerator consumes 1800 J of energy over a certain period of time to keep food cold, how much charge (coulombs) has been moved?

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Zebrowski, Ernest, Jr. Physics for Technicians. New York: McGraw-Hill, 1974.
See especially Chapters 15, 17, 21, 25.

APPENDIX D

Example Application Module:

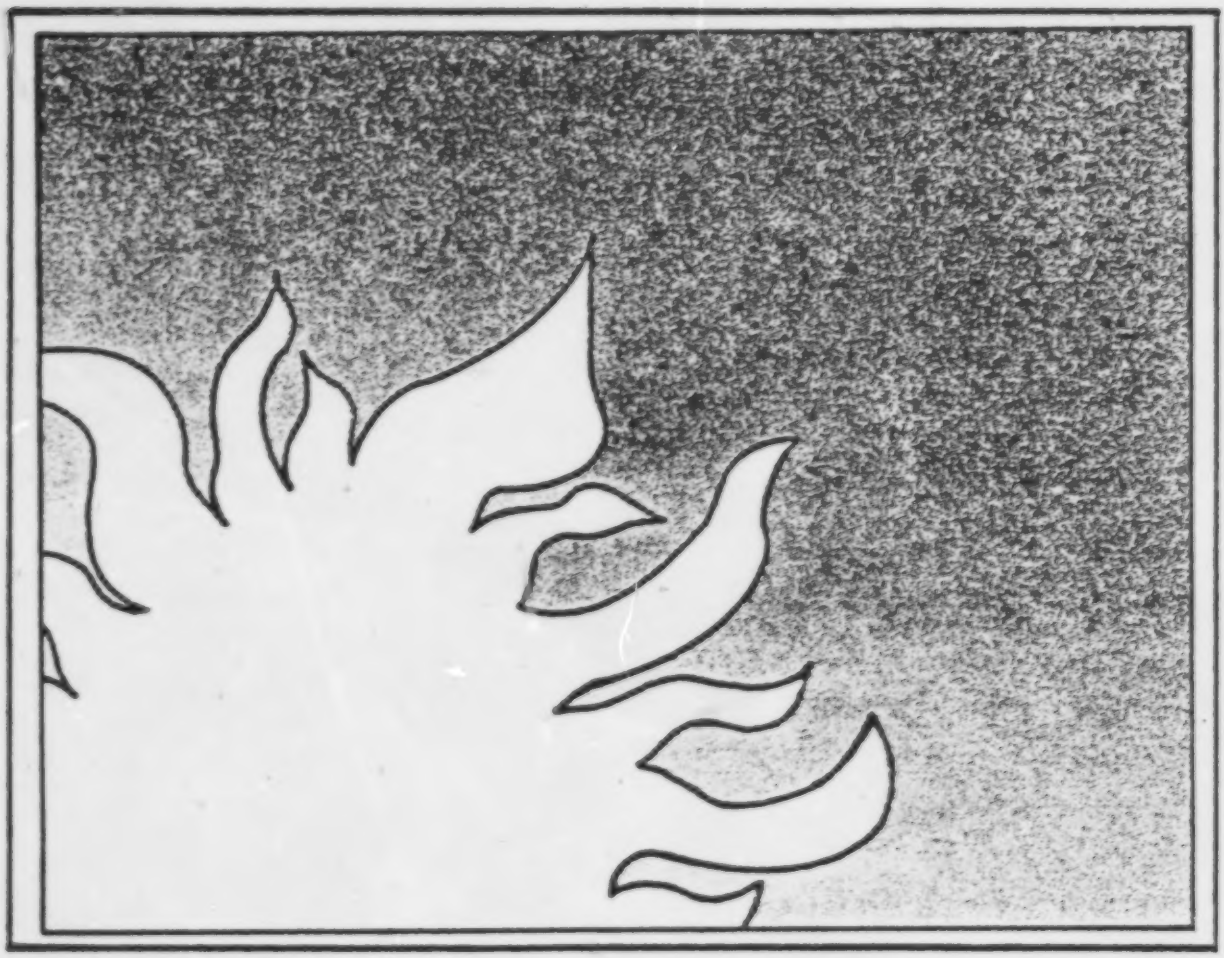
6T2, "Heat Flow Through Insulation"

UTC

UNIFIED TECHNICAL CONCEPTS

MODULE 6-T-2

HEAT FLOW THROUGH INSULATION



THERMAL APPLICATION OF RESISTANCE CONCEPT

Technical Education Research Center - Southwest

TERC - SW

UTC

UNIFIED TECHNICAL CONCEPTS

PRELIMINARY DRAFT - NOT FOR SALE

PRIVATELY CIRCULATED SOLELY FOR REVIEW AND EVALUATION

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TERC-SW

TECHNICAL EDUCATION RESEARCH CENTER - SW

4201 LAKE SHORE DRIVE, SUITE 111

WACO, TEXAS 76710

PREFACE

Why UNIFIED PHYSICS?

Modern industries have an increasing need for technicians who are able to install and maintain complex production equipment. Maintenance of this equipment often requires a high degree of competence in hydraulic, pneumatic, thermodynamic, or optical subsystems, as well as in mechanical and electrical components. The technician must understand the component parts, but also, he must have some understanding of the integrated system.

Institutions seeking to develop modern vocational training programs have often recognized a need for one or more Physics courses to teach physical principles. UNIFIED TECHNICAL CONCEPTS is a modularized system of instruction which seeks to fill this need in a special way.

UNIFIED TECHNICAL CONCEPTS explains how energy is stored, transferred, and controlled. Rather than studying mechanics, fluids, heat, and electricity separately, a unifying concept such as "rate" or "resistance" is presented. Applications of the unified concept to each of the four areas are shown. This approach takes advantage of the analogies which exist among these areas in order to economize the learning process. Students are able to learn general formulas which replace many specialized formulas they would otherwise have to memorize. Furthermore, this UNIFIED approach helps technicians understand relationships between components in the complex equipment.

Careful selection of CONCEPT MODULES and APPLICATIONS MODULES from the UTC materials makes it possible for institutions to prepare "tailor-made" courses which are relevant to each particular vocation. Every module contains "hands-on" laboratory experiences and makes use of practical equipment that is meaningful to the student. Module 1.0, Matter, Units, and Measurement prepares the student for understanding the Concept modules (2.0 - 13.0)

The UNIFIED TECHNICAL CONCEPTS being developed in this program are:

2.0 Force and Force-Like Quantities
3.0 Work and Energy Systems
4.0 Rate
5.0 Momentum
6.0 Resistance
7.0 Power
8.0 Potential and Kinetic Energy
9.0 Force Transformers
10.0 Energy Transformers
11.0 Vibrations and Waves
12.0 Time Constants
13.0 Radiation

Daniel M. Hull, Project Director
Technical Education Research Center-SW
4201 Lake Shore Drive, Suite 111
Waco, Texas 76710

ABOUT UNIFIED TECHNICAL CONCEPT (UTC) MODULES

The UTC modules are being developed by TERC-SW for use in two-year post secondary technical institutions preparing technicians for employment. These instructional modules will also be evaluated for their usefulness to industries for updating their employees in company-sponsored training and to laboratory texts in engineering schools. The modules are being written by technical instructors and physicists and will be tested with students. Each module contains the following elements.

Introduction, which identifies the topic and often includes a rationale for doing the exercises.

Objectives, which clearly tell the student what he is expected to know for satisfactory completion. The objectives are stated in terms of action oriented behaviors and which include such action words as *operates, measures, calculates, identifies,* and *defines,* instead of words with many interpretations such as *know, understand, learn* and *appreciate.*

Discussion, which presents the background theory and techniques supportive to the objectives of the lesson. An understanding of the discussion requires prior math background in high-school algebra. Any other prerequisites to understanding the material will be stated at the beginning of each module.

Materials, which identifies the equipment required to complete the laboratory procedure. A complete equipment list and specifications can be supplied upon request.

Procedures, which is the experiment section or "hands-on" portion of the module. It includes step-by-step instructions. The experiments are designed to reinforce student learning, and data sheets for each experiment are provided in each module.

Exercises, which are included for the purpose of reviewing and reinforcing the points covered in the exercise.

Reference Materials, which are included as supplementary reading/reviewing for the student.

INTRODUCTION

As cost of maintaining desired temperatures for businesses and homes increases rapidly, the need for adequate insulation becomes more important. Insulation slows down (impedes) flow of heat in the same manner that a resistor impedes flow of electrical current. Increased insulation can greatly reduce heat losses in a structure and thereby substantially reduce heating and cooling costs. Previously, the cost of energy has been relatively low and savings brought about by increased insulation did not offset the added cost. Today, however, increased cost of energy has made better thermal design and added insulation a more realistic investment. In this module, the thermal resistance of several commercial insulating materials will be investigated.

PREREQUISITES

Student should have completed Concept Module 6-0, "Resistance," and Application Module 6T1, "Thermal Conductivity," and should have ability to plot data, draw simple graphs and make simple algebraic calculations.

OBJECTIVES

To complete this module, the student should be able to:

- Define:
  - Thermal conductivity.
  - Conductance.
  - Overall heat transfer coefficient.
  - Resistance to heat flow.
- Calculate overall heat transfer coefficient for a given system of wall and insulation. Material and resistance data provided.
- Measure and record temperature difference across several

insulating materials of varying thicknesses, plot data obtained and explain significance of the curves.

DISCUSSION

The concept of thermal conductivity was discussed in Module 6T1, and will be extended in this module with emphasis upon commercial insulating materials. It was pointed out that rate of heat flow through a given thickness of material is given by:

$$H = \frac{kA\ (T_2 - T_1)}{x} \qquad (1)$$

where

H = heat flow rate, Btu/h or cal/s.
k = coefficient of thermal conductivity, $\frac{\text{Btu x in}}{\text{h x ft}^2\ \text{F}^\circ}$ or $\frac{\text{cal x cm}}{\text{h x cm}^2\ \text{C}^\circ}$.
A = area ft^2 or cm^2.
$(T_2 - T_1)$ = difference in temperature between the two surfaces "x" ft or cm apart.
x = thickness of two surfaces considered, ft or cm.

Materials with high thermal conductivities k permit larger heat flow rates than materials with small values of k. For example, concrete has a thermal conductivity of:

$$k = 12\ \frac{\text{Btu x in}}{\text{h x ft}^2\ \text{F}^\circ}$$

whereas fiberglass insulation has a thermal conductivity of:

$$k = 0.25\ \frac{\text{Btu x in}}{\text{h x ft}^2\ \text{F}^\circ}$$

CONDUCTANCE DEFINED

The term conductance is used for heat flow through materials that do not have a uniform or similar structure throughout the considered cross section (inhomogeneous). Conductance is defined as heat flow rate in Btu/hour through one square foot of an inhomogeneous material of a given thickness for a one degree difference in temperature between the two surfaces or faces of

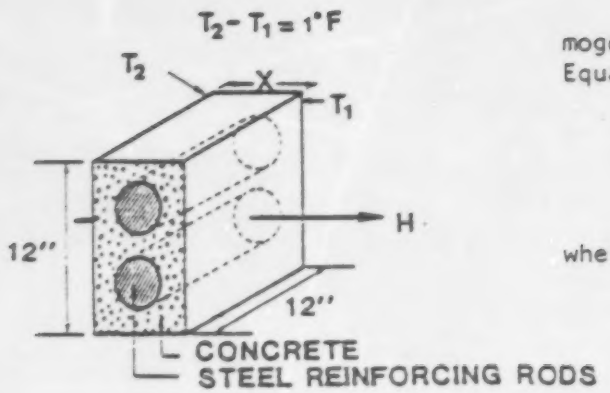


Fig. 1

the material (Figure 1).

Heat transfer by conduction through an inhomogeneous material can be calculated as shown in Equation 2.

$$H = CA\,(T_2 - T_1) \qquad (2)$$

where

H = heat flow rate, Btu/h or cal/s.
A = area, ft^2 or cm^2.
$(T_2 - T_1)$ = difference in temperature between the two surfaces, °F.
C = conductance, $\frac{Btu}{h \times ft^2\ F°}$ or $\frac{cal}{s \times cm^2\ C°}$.

For a material that has a uniform or similar structure throughout (homogeneous) with a specific value for thermal conductivity k, the conductance C is given by:

$$C = \frac{k}{x} \qquad (3)$$

where x is the thickness between the two surfaces of temperatures T_1 and T_2.

Resistance to heat flow is defined as the reciprocal of the conductance.

$$R = \frac{1}{C} \qquad (4)$$

where R = resistance, $\frac{h \times ft^2\ F°}{Btu}$ or $\frac{s \times cm^2\ C°}{cal}$.

Example A will illustrate the use of Equations 2, 3 and 4.

EXAMPLE A: HEAT FLOW THROUGH A BRICK WALL

Given: Heat flow through a 4-inch brick where $k = 9$ Btu . in/hr x ft^2 F° and $x = 4$ inches.

Find: Resistance to heat flow.

Solution:

$$C = \frac{k}{x} = \frac{9}{4} \frac{\text{Btu x in}}{\text{h x ft}^2\ F^\circ \text{ x in}}$$

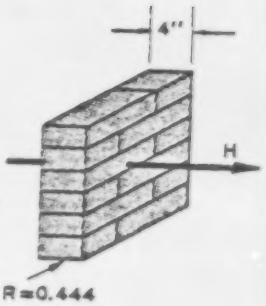
Therefore:

$$C = 2.25 \frac{\text{Btu}}{\text{h x ft}^2\ F^\circ}$$

$$k = \frac{9 \text{ Btu x in}}{\text{h x ft}^2\ F^\circ}$$

and resistance of the 4-inch brick is:

$$R = \frac{1}{C} = \frac{1}{2.25} = 0.444.$$



Note: The units of $\frac{\text{h x ft}^2\ F^\circ}{\text{Btu}}$ are usually omitted.

If a compound wall is made of several different materials, the heat conducted through the wall is given by:

$$H = UA\ (T_2 - T_1) \qquad (5)$$

where

H = heat flow rate, Btu/h or cal/s.
U = overall heat transfer coefficient of wall, $\frac{\text{Btu}}{\text{h x ft}^2\ F^\circ}$ or $\frac{\text{cal}}{\text{s x cm}^2\ C^\circ}$.
A = area, ft^2 or cm^2.
$T_2 - T_1$ = temperature difference between surfaces of the wall, °F or °C.

Overall heat transfer coefficient is simply the overall conductance and so is equal to the reciprocal of the total resistance.

$$U = \frac{1}{R_T} \qquad (6)$$

where total resistance is given by:

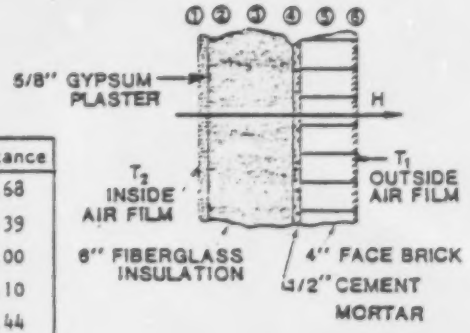
$$R_T = R_1 + R_2 + R_3 + \ldots R_n \qquad (7)$$

and where R_1, R_2, ... R_n are resistances of individual components in the compound wall. Total resistance R_T is commonly referred to as the R-value. To illustrate this concept, consider Example B.

EXAMPLE B: HEAT CONDUCTED THROUGH AN INSULATED WALL

Given: Resistance data below.

Find: Value of total resistance and develop general formulas for overall heat flow rate for the insulated wall illustrated in the figure.



Item	Description	Resistance
1	Inside air film	0.68
2	5/8" gypsum plaster	0.39
3	6" fiberglass insulation	24.00
4	1/2" mortar cement	0.10
5	4" face brick	0.44
6	Outside airfilm	0.17
	Total resistance = R_T =	25.78

Thus, total resistance $R_T = 25.78$. From this and Equation 6, calculate overall heat transfer coefficient as follows:

$$U = \frac{1}{R_T} = \frac{1}{25.78} = 0.03879.$$

Calculate H, heat flow rate, for the innomogeneous wall. Thus, with A and $(T_2 - T_1)$ known, we would have a formula of:

$$H = 0.03879\ A\ (T_2 - T_1).$$

Values of resistances can be found in various air conditioning and refrigeration manuals and handbooks.

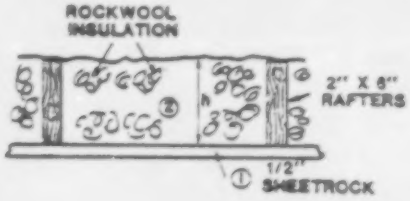
93% of all the resistance comes from the insulation.

Since fiberglass is the most common type of insulation, it would be important to investigate its R-value. The thermal conductivity for fiberglass insulation is:

EXAMPLE C: HEAT CONDUCTED THROUGH A COMPOUND CEILING

Given: Data below.

Find: Thickness of insulating rockwool required to give an R-value of 39 for the ceiling.



Solution:

1 1/2" sheetrock where: $k_s = 6 \left(\frac{Btu \times in}{h \times ft^2 F^\circ}\right)$

2 rockwool insulation where: $k_R = 0.3 \left(\frac{Btu \times in}{h \times ft^2 F^\circ}\right)$

for 1 : $R_s = \frac{1}{C_s} = \frac{x}{k_s} = \frac{1/2"}{6} = 0.0833$

for 2 : $R_R = \frac{1}{C_R} = \frac{x}{k_R} = \frac{h}{0.3}$

$R_T = 39 = 0.0833 + h/0.3$

Solving the above equation for h, we get:

$h = 11.68$ in.

Resistance for the rockwool cannot be calculated yet, because depth is not known.

Total resistance is the sum of the individual resistances.

R-values of 39 are currently being advertised to reduce heating and air conditioning bills by at least 50%.

R-values of 39 can be reached by increasing standard 6" ceiling insulation to 12".

$$k = 0.25 \frac{Btu \times in}{h \times ft^2 F^\circ}$$

Resistance or R-value for 3 inches of fiberglass insulation is then:

$$R = \frac{x}{k} = \frac{3"}{0.25} = 12$$

and resistance or R-value for 6 inches of the same insulation is:

$$R = \frac{x}{k} = \frac{6''}{0.25} = 24.$$

In buying insulation or specifying requirements for insulation, resistance or R-value of the insulation is very useful.

COMPARISON OF INSULATING MATERIALS

MATERIALS

Three heat lamps.
Four oven thermometers.
Containers with trays for holding samples.
Three samples of insulation with different R-values such as:

- Fiberglass (3 thicknesses) sheet.
- Polyethylene sheeting.
- Rockwool.
- Fiberglass - loose or blown.
- Polystyrene (as used in home insulation).

PROCEDURE

1. Place three different insulation samples (coded A, B, C) in trays as shown in Figure 2.
2. Place a thermometer under each material, and one on top of middle sample.
3. Turn on heat lamps; allow system to come to thermal equilibrium (thermometers reach a steady temperature).
4. Record temperatures from each sample in data table.
5. Plot data as shown in Figure 3.
6. How does temperature recorded at under side of each sheet of insulation vary with R-value?

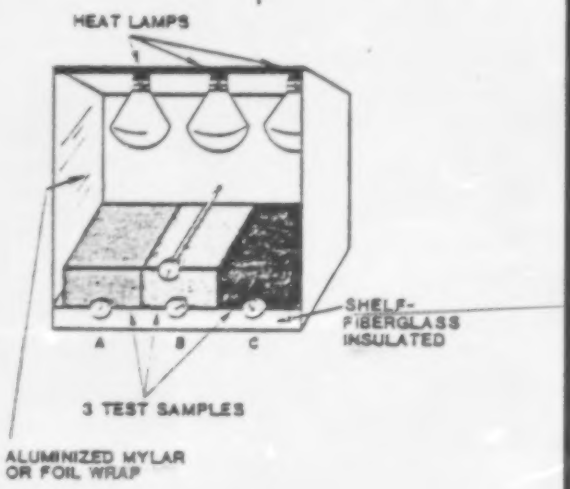


Fig. 2

DATA TABLE			
Sample	Type Insulation	R-Value	T
A			
B			
C			

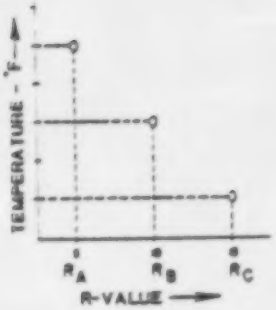


Fig. 3

SELF CHECK

1. Define:
   Thermal conductivity.
   Conductance.
   Resistance to heat flow.
2. Qualitatively describe results of the experiment and explain results of the data plotted in Figure 3.
3. Using data given, calculate overall heat transfer coefficient, $U = 1/R$, for the insulated wall illustrated in Figure 4.

Material	Resistance
1	0.68
2	0.39
3	12.00
4	0.10
5	1.0
6	0.17

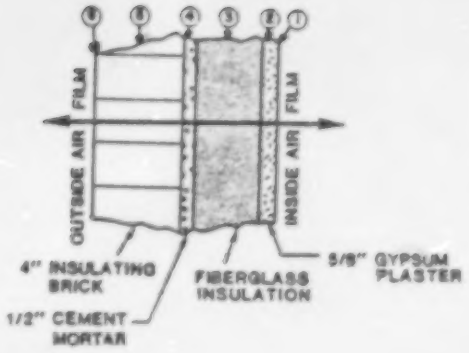


Fig. 4

REFERENCES

Trane Company. Trane Air Conditioning Manual. St. Paul, MN: McGill Graphic Arts, 1970.

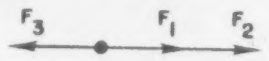
APPENDIX E

Matrix: Energy Systems versus Concepts

CONCEPT FORCE AND FORCELIKE QUANTITIES

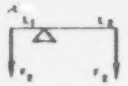
MECHANICAL F or τ

1. Parallel Coplanar Forces



2. Nonparallel Coplanar Forces

3. Torque



4. Torque Wrench

5. Dynamometer

6. Block on an Inclined Plane

7. Structural Forces

FLUID P=F/A

1. Pascal's Principle (Hydraulic Press)
2. Altimeter
3. Aneroid Barometer
4. Atmospheric Pressure
5. Boyle's Law
6. Pressure vs Depth in a Liquid
7. Hydrostatic Paradox
8. Pressure Gauges
   a) Open-tube Manometer
9. Gauge Pressure
10. Absolute Pressure
11. Archimedes Principle
12. Hydraulic Car Lift
13. Partial Pressure (Gas)

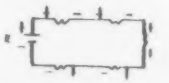
HEAT ΔT

1. Thermometers
2. Temperature Scales
3. Thermocouple
4. Constant Volume Gas
5. Thermometer
6. Linear Expansion $\Delta L = \alpha L_0 \Delta t$
7. Volume Expansion $\gamma = 2\alpha$ $\beta = 3\alpha$
8. Thermal Stress $\frac{F}{A} = Y\alpha\Delta t$
9. Heat Capacity $C = \frac{Q}{\Delta t}$
10. Specific Heat $c = \frac{Q}{M\Delta t}$
11. Calorimetry
12. Convection $H = hA\Delta t$
13. Conduction $H = \frac{KA\,(T_2 - T_1)}{X}$

ELECTRICAL V

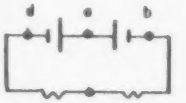
1. Voltage Measurement (Voltmeter)
2. Polarity

3. $E = \Sigma V$

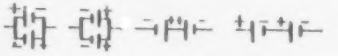


KIRCHOFF'S LOOP RULE

4. Wheatstone Bridge
5. Breakdown Voltage in a Gas
6. Voltage-current Curves for Vacuumdiode, Transistor Diode, Zenerdiode, etc.
7. Potential Difference Between Points in a Circuit



8. "Ground" Check (House Wiring)
9. Terminal Voltage of a Seat of EMF
10. Sliding Wire Potentiometer
11. Four Ways of Connecting EMF



12. Back EMF

APPENDIX F

Module Control Forms

MODULE RECOMMENDATION FORM

Module Number and Title: _____

Date outline required: _____

Module required on or before: _____

1. Recommended Content.

_____

_____

_____

_____

_____

_____

_____

_____

2. Recommended Laboratory Procedures.

_____

_____

_____

_____

_____

_____

_____

_____

FORM #CS5-77

TECHNICAL EDUCATION RESEARCH CENTER · Southwest
4201 Lake Shore Drive, Suite 111 Waco, Texas 76710
Telephone 817 772 8756

Dear

As a follow-up of our letter dated September 1, 1977, I am pleased to enclose the following:

1. Copy of Concept Module(s)
2. .Titles of Application Modules in the subject Concept Module. (See attached Matrix dated November 1, 1977.)
3. List of recommended content for your module(s) - information only - as you can build on these recommendations when you submit the outline on or before the included date(s) and we will approve or recommend changes in your outline within 24 hours so that you may proceed without delay.

Sincerely,

Vernon Woolf
Associate Project Director

VW/jw
Encl.
cc: Dan Hull
Bruce Lube

A non profit public service corporation

PARTS OF A TYPICAL UTC PHYSICS MODULE

INTRODUCTION

This is a summary of the module contents. You may wish to include some specific facts, but the material in this section should be kept general. It might be similar to an abstract for a technical paper. In some instances a rationale of why this material is important for the student to learn could be included.

PREREQUISITES

List any skills or special abilities needed by the student to complete this module. Usually a reference is made to the successful completion of the associated concept module.

OBJECTIVES

These should be stated in well written behavioral terms. A commonly used format that is acceptable is to make a preliminary statement similar to: "At the completion of this module the student will: ("be able to" is an optional comment). Follow this statement with a list of the specific tasks the student will be able to do when he successfully completes the module. Include the level of mastery where appropriate (example: list 3 of the 5 parts of a gizmocker). Also include anything that he might need to complete the objective (example: given an ohmeter measure the current flow across two wires attached to the terminals of a 6 volt battery). Avoid phrases that could be open to intrepretation such as: to know, to understand, to gain knowledge of, to appreciate, etc. Other words thatshould be used include to write, to recite, to list, to compare, etc.

DISCUSSION

Explain the objectives and the parts of the outline you created preferably in the same order presented. Figures, diagrams, and illustrations are helpful especially when practical examples are used. Remember these are technical students, many with poor verbal skills. The more you can relate these materials to familiar examples the more the student will see the practicality of the content.

MATERIALS

This is a list of items needed to complete the procedures and experiments that follow. These experiments should be as realistic and practical as possible. Always relate the experiments to the objectives and the discussion.

PROCEDURES

A step by step sequence of the experiments used to describe the objectives. The emphasis here is HANDS-ON activities to get the student involved in the learning process.

EXERCISES

This section could also be referred to as a selftest, self-check, self-quiz, etc. The intent is to restate the objectives in a question format such that the student can, by answering these questions, insure themselves that they have mastered the objectives of the module.

REFERENCE MATERIALS

Include references that someone might use to find more of similar content as that covered by the module. Include the following information:

1. Full name of author
2. Publishers name and address
3. Published date
4. Title of book or journal and article

TECHNICAL EDUCATION RESEARCH CENTER - Southwest

4201 Lake Shore Drive, Suite 111 Waco, Texas 76710

Telephone 817 - 772 - 8756

Dear Author:

With your cooperation and assistance, concept and applications modules for the first seven concepts in the UTC program are being finished in time for field testing. However, time has been working against us and your deadlines for modules in concepts 8 - 13 are either rapidly approacing or have been passed. Some of the trouble spots found during the development of the first group of modules were as follows:

1. Overlapping content from authors. This does not mean we are discouraging references to or some repetition of the concept ideas. We do want to avoid duplicating experiments and content.
2. Deadlines made which were too near the time the materials were to be used, leaving inadequate time for careful editing, illustrating, and typing.
3. Material being submitted needing major revision causing delays and confusion in module processing and author payment.
4. Some authors have not submitted any written materials and our concern is that a mutual agreement as to content and format be established immediately.

To facilitate overcoming these trouble spots I will be providing you three additional pieces of information to assist you in writing your module(s), including:

1. A copy of the concept module. This will insure that you know the scope of the concept for which you are writing an application.
2. A complete list of proposed titles for all the application modules in that (those) concept(s). Being provided this information should give you some idea of other topics being covered in that concept(s).
3. The third item is a short statement of what should be considered to be the possible content for that applications module. This statement should not dictate but indicate possible content.

Revisions, modifications and deletions must be kept to a minimum, therefore, I am including an authors guide to assist you in providing initially useable materials. The process that will be followed upon receipt of your module is to make an "in-house" rough edit and immediately send your materials to our technical editors. You will be notified when your module has been sent to the technical editors and you should submit for payment as soon after that as possible. Payment is normally made within 30 days. Some delays have been experienced for the following reasons:

1. The module needed an initial type when it was received. This is the first step in determining the number of pages the author is to be paid for.
2. The module needed extensive revisions by the staff and/or author because of content problems.
3. If a module was submitted for one of the later concepts it was given low priority for review. This should no longer be a problem since we are moving into the second phase.

When it returns, illustrations are completed, experiments tested and a final typing made. Duplication and binding completes the process. You are the key to this whole cycle, without your tirely and accurate input everything slows down.

In addition another change in procedure will be instituted immediately, You are required to submit objectives and an outline for approval, prior to drafting your module(s). This should eliminate or diminish problems in trouble spots 1, 3 and 4 previously mentioned. If you are unable to comply with any of these changes please feel free to contact me immediately so that other authors may be assigned your topics.

For you review I am attaching a short description of the format of a completed module. If you have followed the TERC approved outline when you sbumit your rough typed module with legible illustrations, our module approval will be much faster. Your assistance in acheiving these objectives is expected.

Sincerely,

Bruce M. Lube

A non-profit public service corporation

EVALUATION CRITERIA FOR SELECTION OF
UTC APPLICATION MODULES

Module title _____ Module number _____

Energy system _____ Author _____

Concept _____

Technology(s) served _____

Prerequisite modules _____

This module is prerequisite to the following modules _____

Discussion content

Other modules with similar content _____

_____

Description of laboratory

Laboratory demonstrates ☐ basic physics ☐ practical application

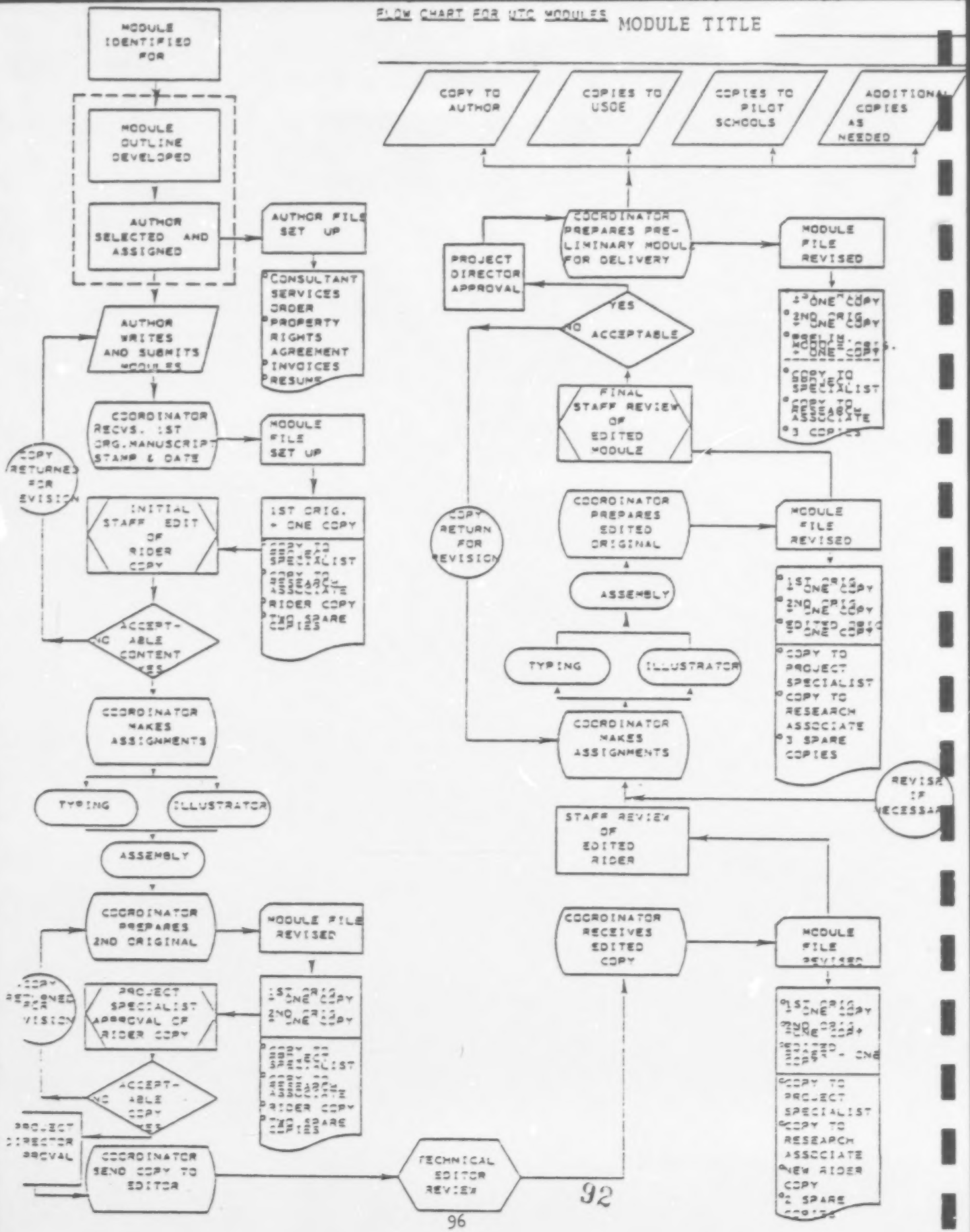
Other modules with similar laboratories _____

Comments

	Date	Initials
Form Completed		
☐ Approved by Project Mgr. / ☐ Disapproved (see comments)		
Title and number assigned		
Recommended outline prepared		

	Date	Initials
Author assigned		
Lab test conducted		
Equipment list prepared		
Completed module approved		

Form #CS5-78


FLOW CHART FOR VTC MODULES
MODULE TITLE
MODULE IDENTIFIED FOR
MODULE OUTLINE DEVELOPED
AUTHOR SELECTED AND ASSIGNED
AUTHOR FILE SET UP
CONSULTANT SERVICES ORDER
PROPERTY RIGHTS AGREEMENT
INVOICES
RESUME
AUTHOR WRITES AND SUBMITS MODULES
COORDINATOR RECVS. 1ST ORG. MANUSCRIPT STAMP & DATE
MODULE FILE SET UP
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INITIAL STAFF EDIT OF RIDER COPY
1ST ORIG. + ONE COPY
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COPY TO RESEARCH ASSOCIATE
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ACCEPT-ABLE CONTENT
COORDINATOR MAKES ASSIGNMENTS
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COORDINATOR PREPARES 2ND ORIGINAL
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COPY TO RESEARCH ASSOCIATE
3 COPIES
COPY TO AUTHOR
COPIES TO USOE
COPIES TO PILOT SCHOOLS
ADDITIONAL COPIES AS NEEDED

UTC - MODULE ASSIGNMENT PLAN

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11 MAR 77
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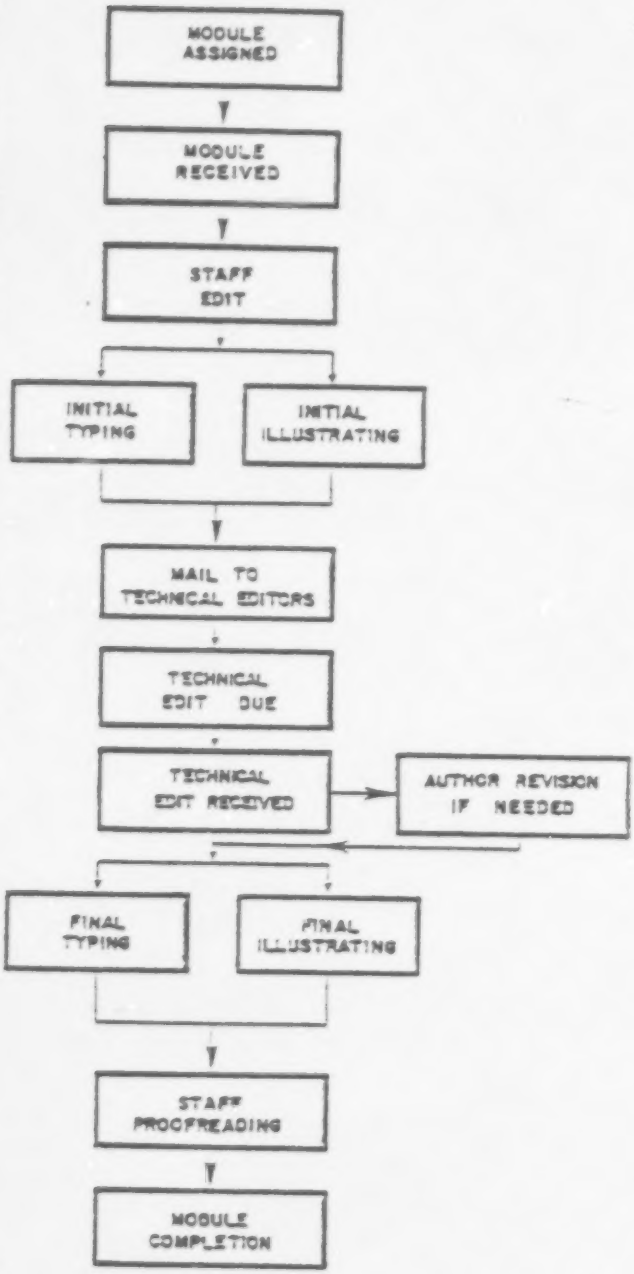

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MODULE NO.	
AUTHOR	
DATE ASSIGNED	
DATE DUE	
DATE RECEIVED	
STAFF EDIT	
INITIAL TYPING	
INITIAL ILLUSTRATING	
MAIL TO TECHNICAL EDITORS	
TECHNICAL EDIT DUE	
TECHNICAL EDIT RECEIVED	
AUTHOR REVISION IF NEEDED	
FINAL TYPING	
FINAL ILLUSTRATING	
STAFF PROOFREADING	
MODULE COMPLETION	

* I AGREE TO THE ABOVE LISTED DUE DATE.

_____
(AUTHOR'S SIGNATURE)

* I CANNOT MEET THE ABOVE LISTED DUE DATE. IF ACCEPTABLE, I PROPOSE TO HAVE MY ASSIGNED MODULE COMPLETED BY _____.
(DATE)

APPENDIX G

Modules Used in Experimental Instructional Programs

NORTH CENTRAL TECHNICAL INSTITUTE

CONCEPT MODULE 1-0 - MATTER, UNITS AND MEASUREMENTS

Application Module 1S6 - Dimensional Analysis

CONCEPT MODULE 2-0 - FORCE AND FORCELIKE QUANTITIES

Application Modules 2E1 - Potential Difference
2M1 - Resolution and Composition of Vectors
2M2 - Torque and Equilibrium
2M3 - Structural Forces and Torque
2M4 - Stress and Strain
2F2 - Density, Buoyancy and Specific Gravity
2F3 - Hydraulic Jack
2T1 - Thermometers
2T2 - Temperature Difference and Heat Flow

CONCEPT MODULE 3-0 - WORK AND ENERGY

Application Modules 3F1 - Work Done by a Water Pump
3T1 - Heat of Fusion
3T5 - Fundamentals of Air Conditioning
3T6 - Calorimeter Experiment

CONCEPT MODULE 4-0 - RATE

Application Modules 4E1 - Direct Current
4M1 - Velocity and Acceleration Graphs
4M2 - Velocity at a Constant Acceleration
4M3 - Displacement at a Constant Acceleration
4F4 - Flow Rate Measurement with a Venturi Meter
4T1 - Heating, Cooling Rate
4T2 - Rate of Heat Conduction

CONCEPT MODULE 5-0 - MOMENTUM

Application Modules 5E1 - Inductance Coils
5M1 - Angular Momentum in a Flywheel

CONCEPT MODULE 6-0 - RESISTANCE

Application Modules 6E1 - Ohm's Law
6E3 - Series and Parallel Resistors
6E5 - Resistance of Conductors
6E6 - Thermistors
6M1 - Static and Kinetic Friction
6M2 - Effects of Lubricants
6F2 - Laminar and Turbulent Flow
6T1 - Thermal Conductivity
6T5 - Heat Flow Through Insulation

CONCEPT MODULE 7-0 - POWER

Application Modules 7E2 - Electric Heater
7E3 - Electrical Power Measurement
7E5 - Prony Brakes
7M5 - Horespower
7T3 - Heat Exchanger

CONCEPT MODULE 8-0 - POTENTIAL AND KINETIC ENERGY

Application Modules 8E3 - Energy Stored in a Battery
8F1 - Energy Stored in Large Tanks/Torricelli's Theorem

CONCEPT MODULE 9-0 - FORCE TRANSFORMERS

Application Modules 9M1 - Levers
9M2 - Wedge-Inclined Plane
9M5 - Block and Tackle
9M6 - Differential Hoist

CONCEPT MODULE 10-0 - ENERGY TRANSFORMERS

Application Modules 10E3 - Photovoltaic Materials
10M1 - Strain Gage
10M2 - Accelerometer
10F1 - Pressure Elements/Bourdon Tube
10F2 - Fluid Flow Measuring Devices
10F3 - Turbines
10F4 - Aneroid Barometer
10F5 - Differential-Pressure Transducer
10T1 - Thermal Expansion/Automobile Water Thermostat
10T2 - Thermal Expanison/Bimetallic Strips
10T3 - Temperature Measuring Devices
10T4 - Pyrometer
10T5 - Generators/Steam

CONCEPT MODULE 11-0 - VIBRATIONS AND WAVES

CONCEPT MODULE 12-0 - TIME CONSTANTS

CAMDEN COUNTY COLLEGE

CONCEPT MODULE 1-0 - MATTER, UNITS AND MEASUREMENTS

Application Module 1S6 - Dimensional Analysis

CONCEPT MODULE 2-0 - FORCE AND FORCELIKE QUANTITIES

Application Modules 2E1 - Potential Difference
2M1 - Resolution and Composition of Vectors
2M2 - Torque and Equilibrium
2F1 - Atmospheric Pressure
2F2 - Density, Buoyancy and Specific Gravity
2T1 - Thermometers
2T2 - Temperature Difference and Heat Flow

CONCEPT MODULE 3-0 - WORK AND ENERGY

Application Modules 3F1 - Work Done by a Water Pump
3T6 - Calorimeter Experiment

CONCEPT MODULE 4-0 - RATE

Application Modules 4E1 - Direct Current
4M1 - Velocity and Acceleration Graphs
4M2 - Velocity at a Constant Acceleration
4M3 - Displacement at a Constant Acceleration
4F4 - Flow Rate Measurement with a Venturi Meter
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CONCEPT MODULE 5-0 - MOMENTUM

Application Modules 5E1 - Inductance Coils
5M1 - Angular Momentum in a Flywheel

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6E3 - Series and Parallel Resistors
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6M2 - Effects of Lubricants
6F2 - Laminar and Turbulent Flow
6T1 - Thermal Conductivity
6T5 - Heat Flow Through Insulation

CONCEPT MODULE 7-0 - POWER

Application Modules 7E2 - Electric Heater
7E3 - Electrical Power Measurement
7E5 - Prony Brakes
7M5 - Horsepower
7T3 - Heat Exchanger

CONCEPT MODULE 8-0 - POTENTIAL AND KINETIC ENERGY

Application Modules 8E1 - Energy Stored in a Capacitor
8E3 - Energy Stored in a Battery
8M2 - Rotational Kinetic Energy (The Flywheel)
8F1 - Energy Stored in Large Tanks/Torricelli's Theorem
8F3 - Pitot Tube

CONCEPT MODULE 9-0 - FORCE TRANSFORMERS

Application Modules 9E1 - Electrical Transformers
9M1 - Levers
9M2 - Wedge-Inclined Plane
9M3 - Drive Systems
9M5 - Block and Tackle
9M6 - Differential Hoist

CONCEPT MODULE 10-0 - ENERGY TRANSFORMERS

CONCEPT MODULE 11-0 - VIBRATIONS AND WAVES

CONCEPT MODULE 12-0 - TIME CONSTANTS

TEXAS STATE TECHNICAL INSTITUTE

CONCEPT MODULE 1-0 - MATTER, UNITS AND MEASUREMENTS

CONCEPT MODULE 2-0 - FORCE AND FORCELIKE QUANTITIES

CONCEPT MODULE 3-0 - WORK AND ENERGY

CONCEPT MODULE 4-0 - RATE

CONCEPT MODULE 5-0 - MOMENTUM

CONCEPT MODULE 6-0 - RESISTANCE

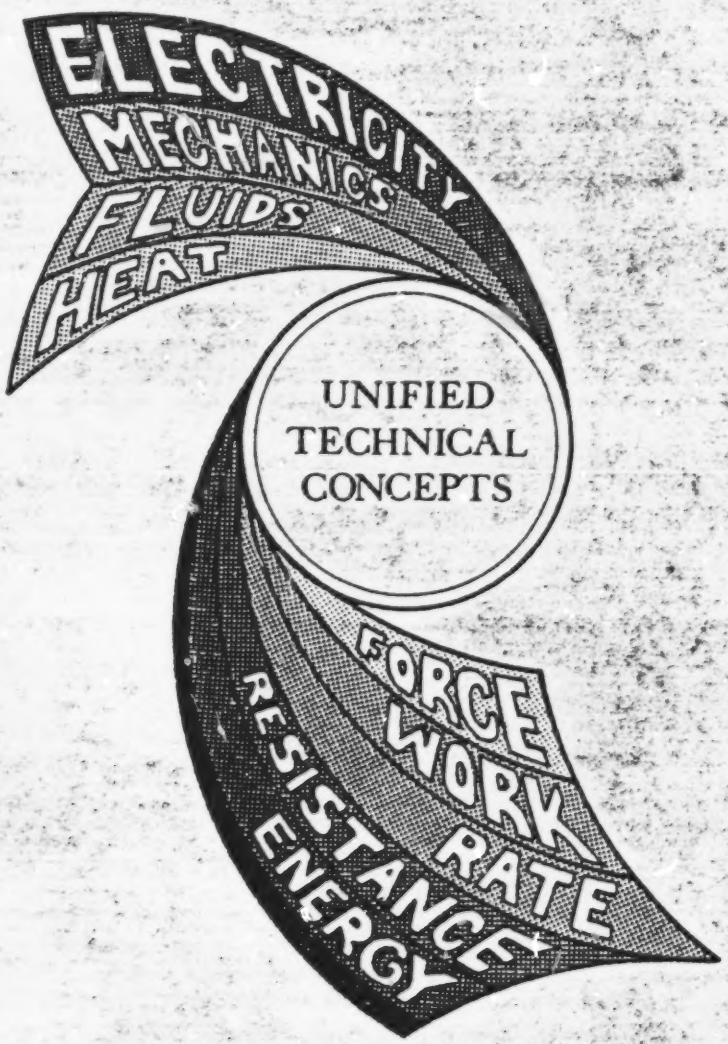
CONCEPT MODULE 7-0 - POWER

APPENDIX H

Pamphlet:

Unified Technical Concepts

a different approach to teaching
TECHNICAL PHYSICS



UTC

UNIFIED TECHNICAL CONCEPTS

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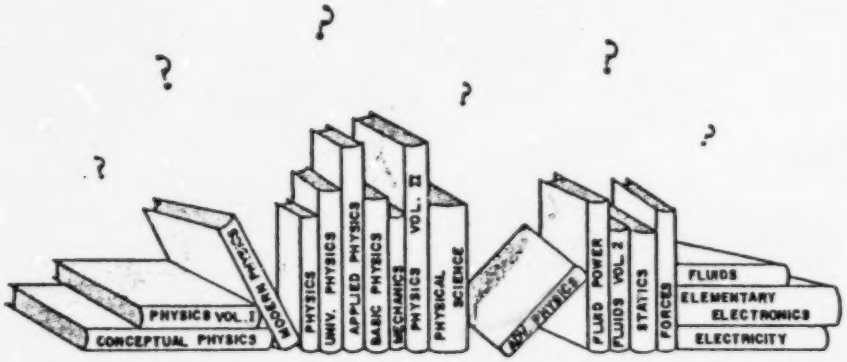
TERC-SW

TECHNICAL EDUCATION RESEARCH CENTER - SW
4201 LAKE SHORE DRIVE, SUITE 111
WACO, TEXAS 76710

MAINTENANCE OF MODERN PRODUCTION EQUIPMENT OFTEN REQUIRES A HIGH DEGREE OF COMPETENCE IN MORE THAN ONE SYSTEM. COMPLEX MODERN EQUIPMENT OFTEN CONTAINS COMBINATIONS OF HYDRAULIC, THERMODYNAMIC, PNEUMATIC, OR OPTICAL SYBSYSTEMS, AS WELL AS MECHANICAL AND ELECTRICAL COMPONENTS. THE SUBSYSTEMS AND COMPONENTS APPEAR, NOT IN ISOLATION, BUT AS INTERDEPENDENT PARTS OF SUCH COMPLEX SYSTEMS. CONSEQUENTLY A MODERN TECHNICIAN MUST UNDERSTAND NOT ONLY THE SEPARATE SUBSYSTEMS, BUT THEIR INTERRELATIONSHIPS AND THE ROLE THEY PLAY IN THE INTEGRATED SYSTEM AS A WHOLE.



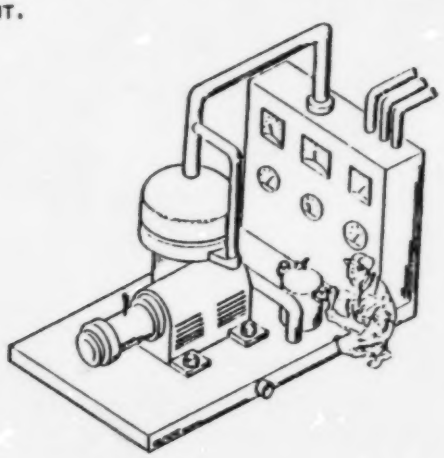
INSTITUTIONS WHICH SEEK TO DEVELOP MODERN VOCATIONAL TRAINING PROGRAMS HAVE TRADITIONALLY INCLUDED ONE OR MORE PHYSICS COURSE IN THE CURRICULUM. PHYSICS FACULTY HAVE DEVELOPED VARIOUS COURSES IN "TECHNICAL" OR "APPLIED" PHYSICS TO MEET THE NEEDS OT THE TECHNICAL TRAINING PROGRAMS. NOW, BUILDING UPON THEIR EXPERIENCES, A NEW AND DIFFERENT APPROACH TO TEACHING TECHNICAL PHYSICS IS BEING INTRODUCED. THIS APPROACH SEEKS TO REORGANIZE THE SUBJECT CONTENT IN SUCH A WAY AS TO HIGHLIGHT AND TAKE ADVANTAGE, PEDAGOGICALLY, OF THE UNIFYING CONCEPTS WHICH OCCUR NATURALLY IN RELATED AREAS OF PHYSICS AND ENGINEERING.

UNIFIED TECHNICAL CONCEPTS

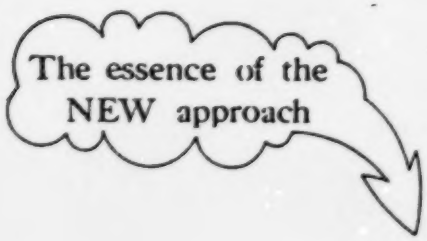
Why a different approach to teaching Technical Physics ?

NEW AND EXCITING VOCATIONAL AND TECHNICAL FIELDS ARE CONTINUALLY DEVELOPING. TODAY, FOR EXAMPLE, SKILLED TECHNICIANS ARE AT WORK IN FIELDS OF LASER TECHNOLOGY, NUCLEAR POWER, ELECTRO-OPTICAL AND BIO-MEDICAL TECHNOLOGY. TOMORROW THESE TECHNICIANS MAY BE NEEDED TO SUPPORT NEW TECHNOLOGIES DEVELOPED TO SOLVE THE WORLD'S ENERGY PROBLEMS. AS A RESULT, PRE-EMPLOYMENT TRAINING FOR CHANGING OCCUPATIONS HAS FORCED SCHOOLS TO CONSIDER MAJOR REORGANIZATIONS OF COURSE CONTENT ON MANY CAMPUSES.

MODERN INDUSTRIES HAVE EXPERIENCED AN INCREASING NEED FOR TECHNICIANS AND MECHANICS WHO CAN INSTALL AND MAINTAIN COMPLEX PRODUCTION EQUIPMENT.



This approach, described as a modularized system of instruction which emphasizes unifying technical concepts, relies heavily on analogies and relationships of basic concepts applied to traditional fields of physics and engineering. It seeks to provide the technician with FLEXIBILITY and DIVERSITY in the application of his basic skills.

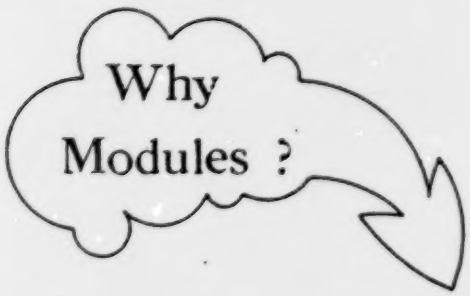


The modularized system of UNIFIED TECHNICAL CONCEPTS is being developed for students in post-secondary technical and vocational programs by Technical Education Research Center - Southwest. This system of instruction includes CONCEPT MODULES which treat the important physics concepts basic to any technical physics course and explain how these concepts serve to unify mechanical, fluid, thermal and electrical systems. The (13) CONCEPT MODULES ARE:

Matter, Units and Measurements
Force and Forcelike Quantities
Work and Energy
Rate
Momentum
Resistance
Power
Potential and Kinetic Energy
Force Transformers
Energy Transformers
Vibrations and Waves
Time Constants
Radiation

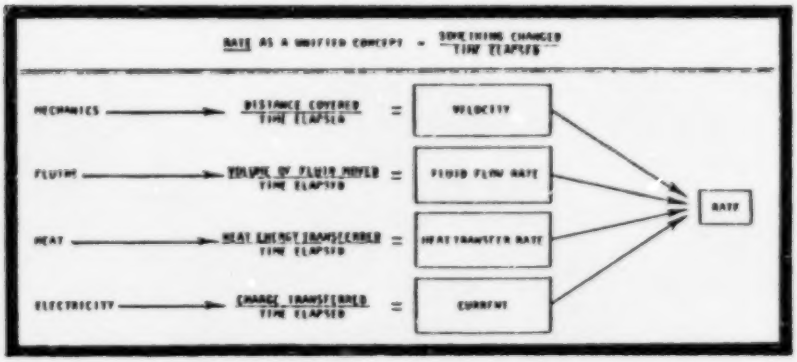
For each CONCEPT MODULE, several APPLICATIONS MODULES will be available to demonstrate the use of basic physics concepts in the fields of mechanics, fluid, heat and electricity. The APPLICATIONS MODULES will reinforce the unifying character of basic physics concepts in the different fields.

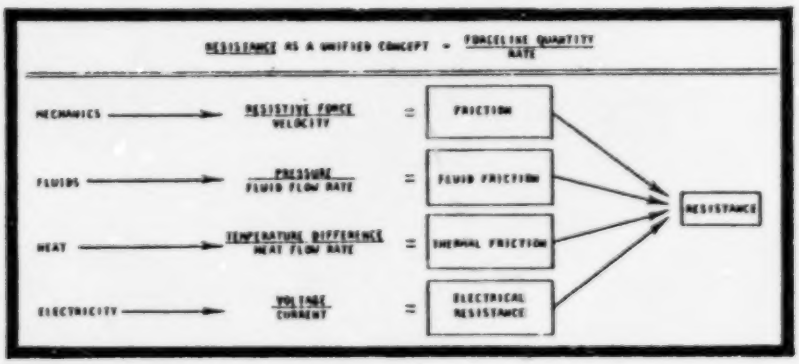
Modularized instructional materials will introduce unified concepts by means of practical examples where possible. For example, equipment such as shock absorbers, torque wrenches, air ducts, building insulation and roller bearings ... rather than Van de Graff generators and air tables ... will be used in learning physics.



Careful selection from the CONCEPT MODULES and the APPLICATIONS MODULES will make it possible for institutions to prepare "tailor-made" courses which are relevant to each particular vocation. Each module will contain "hands-on" laboratory experiences and will make use of practical equipment that is meaningful to the student.

THE FOLLOWING CHARTS ILLUSTRATE HOW BASIC CONCEPTS SUCH AS RATE AND RESISTANCE SERVE AS UNIFYING THEMES IN MECHANICS, FLUIDS HEAT AND ELECTRICITY





THE PROJECT, WHICH WILL BE COMPLETED IN 1979, CALLS FOR THE DEVELOPMENT, TEST AND EVALUATION OF APPROXIMATELY 250 MODULES. THE 158 MODULES WHICH HAVE BEEN IDENTIFIED AND ARE COMPLETED OR ARE BEING DEVELOPED ARE LISTED ON THE FOLLOWING PAGES. THE REMAINING 92 MODULES ARE STILL BEING IDENTIFIED.

UTC CONCEPT AND APPLICATION MODULES

1-0 MATTER, UNITS AND MEASUREMENTS

1S1 FORMULA INTERPRETATION
1S2 INTERNATIONAL SYSTEM OF UNITS
1S3 LOGARITHMS
1S4 PRECISION AND ACCURACY MEASUREMENTS
1S5 LAB REPORTS
1S6 DIMENSIONAL ANALYSIS

} BEING REVISED

2-0 FORCE AND FORCELIKE QUANTITIES

2E1 POTENTIAL DIFFERENCE
2E2 SERIES AND PARALLEL ARRANGEMENTS OF SOURCES OF ELECTRO-MOTIVE FORCES
2E3 MAGNETIC FIELDS
2E4 ELECTRIC FIELDS
2E5 VOLT-OHM-MILLIAMMETER
2M1 RESOLUTION AND COMPOSITION OF VECTORS
2M2 TORQUE AND EQUILIBRIUM
2M3 STRUCTURAL FORCES AND TORQUE
2M4 STRESS AND STRAIN
2F1 ATMOSPHERIC PRESSURE
2F2 DENSITY, BUOYANCY AND SPECIFIC GRAVITY
2F3 HYDRAULIC JACK
2F4 MANOMETERS
2T1 THERMOMETERS
2T2 TEMPERATURE DIFFERENCE AND HEAT FLOW
2T3 THERMAL STRESS

3-0 WORK AND ENERGY

3M1 BICYCLE GENERATOR/ERGOMETER
3F1 WORK DONE BY A WATER PUMP
3F2 WORK DONE BY A HYDRAULIC LIFT
3T1 HEAT OF FUSION
3T2 HEAT OF VAPORIZATION
3T3 FUNDAMENTALS OF AIR CONDITIONING
3T4 CALORIMETER EXPERIMENT

4-0 RATE

4E1 DIRECT CURRENT
4E2 RATE OF CHARGING AND DISCHARGING A BATTERY
4M1 GRAPHICAL APPROACH TO RECTILINEAR MOTION
4M2 VELOCITY AT A CONSTANT ACCELERATION
4M3 DISPLACEMENT AT A CONSTANT ACCELERATION
4F1 FLOW RATE MEASUREMENT WITH A VENTURI METER
4T1 HEATING, COOLING RATE
4T2 RATE OF HEAT CONDUCTION

5-0 MOMENTUM

5E1 INDUCTANCE COIL
5M1 ANGULAR MOMENTUM/FLYWHEEL
5M2 PILEDRIVER
5F1 ROCKET ENGINES
5F2 JET NOZZLES
5F3 WATER HAMMER

6-0 RESISTANCE

6E1 OHM'S LAW
6E2 INTERNAL RESISTANCE IN A BATTERY
6E3 SERIES AND PARALLEL RESISTORS
6E4 CONDUCTORS, SEMICONDUCTORS AND INSULATORS
6E5 RESISTANCE OF CONDUCTORS
6E6 THERMISTORS
6M1 STATIC AND KINETIC FRICTION
6M2 EFFECT OF LUBRICANTS
6M3 ROLLING FRICTION
6M4 PRESS, SHRINK AND SLIDING CONTACT
6F1 LAMINAR AND TURBULENT FLOW
6F2 FLUID RESISTANCE IN PIPES
6F3 SHOCK ABSORBER
6F4 VISCOSITY
6T1 THERMAL CONDUCTIVITY
6T2 HEAT FLOW THROUGH INSULATION

7-0 POWER

7E1 ELECTRICAL HEATER
7E2 ELECTRICAL POWER MEASUREMENT
7E3 PRONY BRAKE
7E4 EFFICIENCY OF ELECTRIC MOTORS AND GENERATORS
7E5 ELECTRICAL POWER CONSUMPTION
7M1 HORSEPOWER
7F1 HYDRAULIC POWER
7F2 POWER TO MOVE A FLUID THROUGH A SYSTEM
7F3 LIFT PUMP POWER
7T1 POWER RATE OF AIR CONDITIONERS
7T2 HEAT EXCHANGER

8-0 POTENTIAL AND KINETIC ENERGY

8E1 ENERGY STORED IN A CAPACITOR
8E2 ENERGY STORED IN A BATTERY
8M1 KINETIC AND POTENTIAL ENERGY OF A SPRING
8M2 ROTATIONAL KINETIC ENERGY (THE FLYWHEEL)
8M3 PILEDRIVER/FORGING HAMMER
8M4 EROSION/SAND BLASTING
8F1 ENERGY STORED IN LARGE TANKS/TORRICELLI'S THEOREM
8F2 VENTURI METER
8F3 PITOT TUBE
8F4 ENERGY CONVERSION IN A FLUID SYSTEM
8T1 HEAT STORAGE SYSTEMS
8T2 ELECTRICAL EQUIVALENT OF HEAT
8T3 MECHANICAL EQUIVALENT OF HEAT
8T4 THERMAL DRYING

9-0 FORCE TRANSFORMERS

9E1 ELECTRICAL TRANSFORMERS
9M1 LEVERS
9M2 WEDGE-INCLINED PLANE
9M3 DRIVE SYSTEMS
9M4 COMPOUND FORCE TRANSFORMERS
9M5 BLOCK AND TACKLE
9M6 DIFFERENTIAL HOIST
9M7 CAMS AND ECCENTRICS
9M8 GEARS AND GEAR TRAINS
9F1 HYDRAULIC PRESS

10-0 ENERGY TRANSFORMERS

10E1 GENERATORS/ELECTRIC

10E2 ALTERNATORS
10E3 PHOTOVOLTAIC MATERIALS
10E4 SOLENOIDS AND RELAYS
10M1 STRAIN GAGE
10M2 ACCELEROMETER
10M3 ELEMENTS OF ENERGY CONSERVATION
10F1 PRESSURE ELEMENTS/BOURDON TUBE
10F2 FLUID FLOW MEASURING DEVICES
10F3 TURBINES
10F4 ANEROID BAROMETER
10F5 DIFFERENTIAL-PRESSURE TRANSDUCER
10F6 WIND POWER
10T1 THERMAL EXPANSION/AUTOMOBILE WATER THERMOSTAT
10T2 THERMAL EXPANSION/BIMETALLIC STRIPS
10T3 TEMPERATURE MEASURING DEVICES
10T4 PYROMETER
10T5 GENERATORS/STEAM
10T6 GENERATORS (THERMOELECTRIC)
10T7 SOLAR COLLECTORS

11-0 VIBRATIONS AND WAVES

11E1 BASIC CHARACTERISTICS OF ALTERNATING VOLTAGES AND CURRENTS
11E2 PHASE RELATIONSHIPS
11E3 OSCILLOSCOPE
11E4 RECTIFIERS
11M1 SPEED OF SOUND IN VARIOUS MATERIALS
11M2 REFLECTION AND ABSORPTION OF SOUND ENERGY
11M3 VIBRATION ISOLATION
11F1 CAVITY VIBRATIONS/STANDING WAVES
11F2 SOUND SPEAKERS
11F3 SPEAKER ENCLOSURES
11F4 REVERBERATION TIME
11F5 RESONANCE

12-0 TIME CONSTANTS

12E1 RC CIRCUITS
12E2 RLC CIRCUITS
12E3 RL CIRCUITS
12M1 SHOCK ISOLATION SYSTEMS/ABSORBER
12M2 SHOCK ISOLATION SYSTEMS/MACHINERY MOUNTING
12T1 RESPONSE TIME OF THERMOCOUPLES

13-0 RADIATION

13E1 ELECTROMAGNETIC INDUCTION
13E2 ELECTRIC FIELDS
13E3 PHOTOELECTRIC EFFECT
13E4 STATIC ELECTRICITY
13M1 MAGNETIC FIELDS
13M2 GRAVITY
13L3 LIGHT SOURCES
13L4 SPECTROSCOPE
13L5 REFLECTION (MIRRORS)
13L6 REFRACTION (LENSES)
13L7 INTERFERENCE (HOLOGRAPHY/NDT)
13L8 DIFFRACTION AND POLARIZATION
13L9 INVERSE SQUARE LAW APPLICATIONS

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